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LAYOUT OF BOILER AND LOCATION OF VARIOUS EQUIPMENT AND THEIR BASIC FUNCTIONS.

The mutual arrangement of the gas ducts of a boiler and the direction of combustion products in them determine what is called the boiler layout which may be II-, T-, N-, U- shaped, four pass or tower type. Among them the II – shaped layout in most popular (Fig-1), the furnace is arranged in an ascending shaft and the convective heating surfaces are arranged in a parallel descending shaft. Its advantage is that fuel is supplied and gases are removed at the bottom, which is convenient for removal of liquid slag.

Furnace : A boiler furnace is that space under or adjacent to a boiler in which fuel is burned and from which the combustion products pass into the boiler proper. It provides a chamber in which the combustion reaction can be isolated and confined so that the reaction remains a controlled force. In addition it provides support or enclosure for the firing equipment.

Boiler Drum : The function of boiler drum is to separate the water from the steam generated in the furnace walls and to reduce the dissolved solid contents of the steam to below the prescribed limit of 1 ppm. The drum is located on the upper front of boiler.

Economizer : The purpose of economizer is to preheat the boiler feed water before it is introduced into the drum by recovering heat from the flue gases leaving the boiler. The economizer is located in the boiler rear gas pass below the rear horizontal super heater.

Superheater : There are three stages of superheater besides the side walls and extended side walls. The first stage consists of horizontal superheater of convection mixed flow type with upper and lower banks located above economizer assembly in the rear pass. The upper bank terminates into hanger tubes which are connected to outlet header of the first stage superheater. The second stage superheater consists of pendant platen which is of radiant parallel flow type. The third stage superheater pendant space is of convection parallel flow type.

Reheater: The function of Reheater is to reheat the steam coming out from high pressure turbine. The reheater is composed of two sections. The front pendant section and rear pendant section.

Burners : There are total twenty four pulverized coal burners for corner fired boilers and twelve oil burners provided each in between two pulverized fuel burners. An evident from name itself, these are used for burning pulverized coal or oil.

Ignitors : There are twelve igniters per boiler. The atomizing air for igniters is taken from plant air compressors at 7 kg /cm^2 (gauge)

Fig-1 shows a symbolic arrangement of various accessories of a 210 MW Boiler.

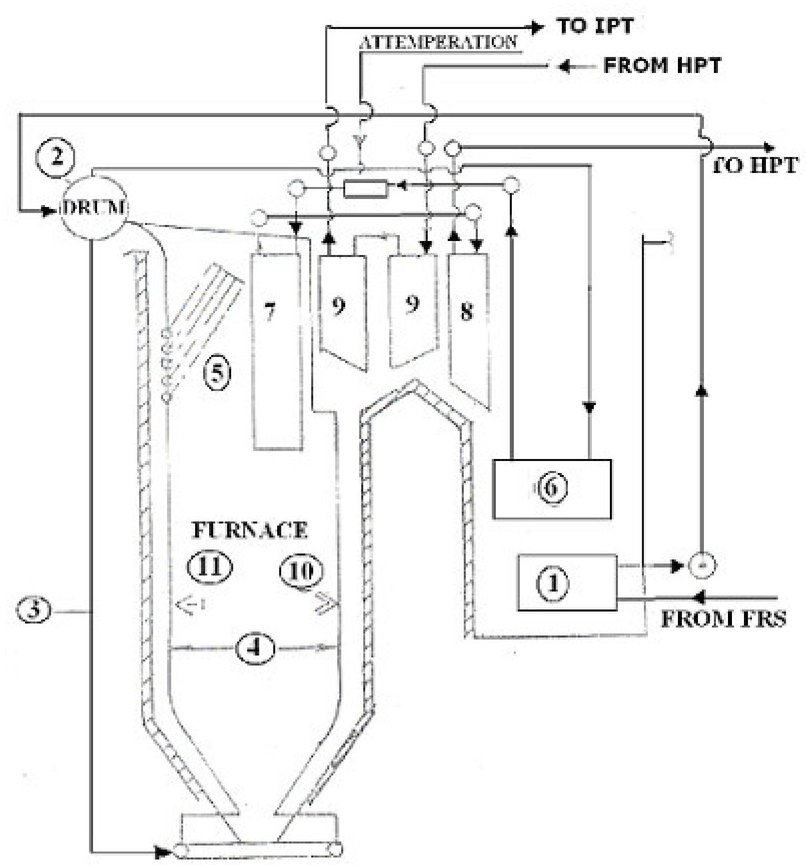

Fig-1
ARRANGEMENT OF BOILER ACCESSORIES

The accessories include –

1. Economizer
2. Boiler Drum
3. Down comers
4. Water walls
5. Water wall plates (used for low-pressure boilers)
6. Primary super heater
7. Platen super heater
8. Final Super heater
9. Reheater
10. Burner
11. Ignitors.

A brief note on some of the major components shows in figure – 1 has been listed in the following paragraph.

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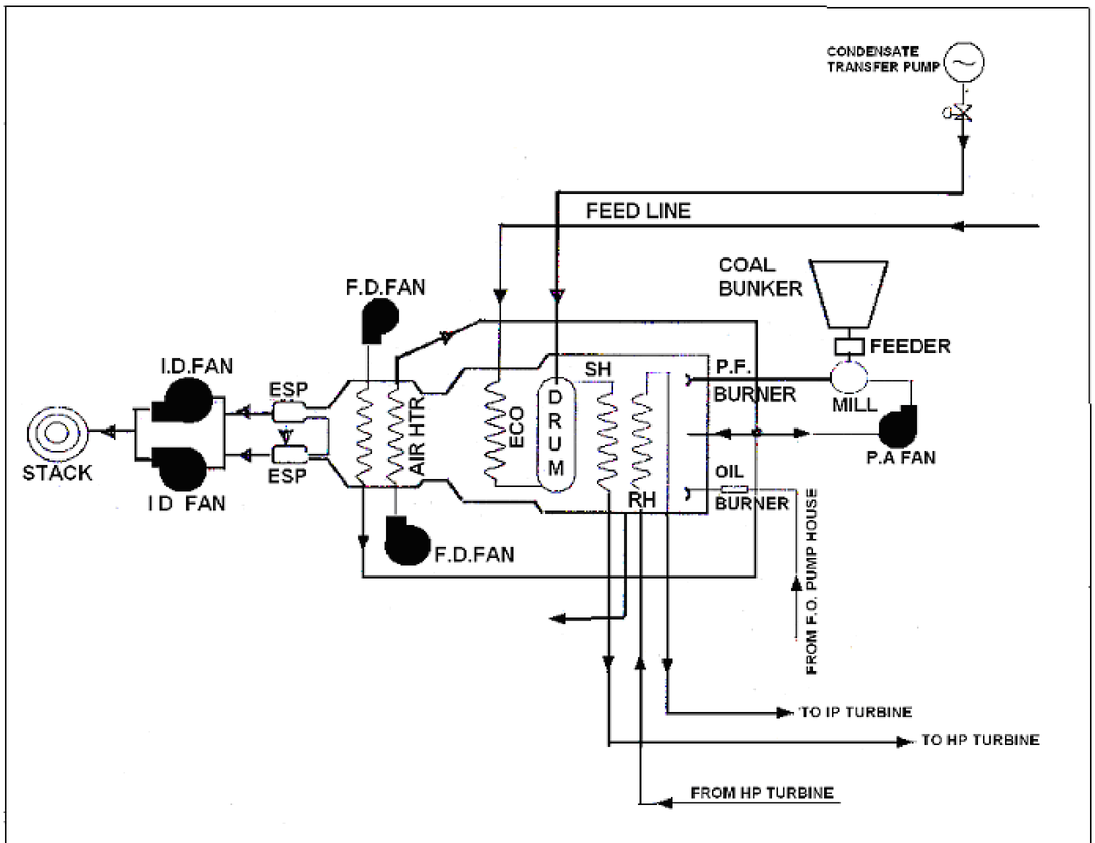


LAYOUT OF BOILER AND AUXILIARIES Fig-2

Figure – 2 gives a symbolic representation of the different boiler auxiliary equipment and their major interconnections.
A brief note on various auxiliary equipment has been given in the following sections.

Coal Bunker: Processed coal after crushing from the Coal Handling Plant is stored in silos (Coal Bunkers). Generally, these bunkers are made up of welded steel plates. These are located on top of the mills so as to aid in gravity feeding of coal.

Coal Feeders: Each mill is provided with a drag link chain / rotary / gravimetric feeder to transport raw coal from the bunker to the inlet chute, leading to mill at a desired rate.

Mills: There are six mills (25% capacity each) for every 210 MW units, located adjacent to the furnace at ‘O’ M level. These Mills pulverize coal to the desired fineness to be fed to the furnace for combustion.

P.A. Fan: The primary air fans are designed for handling hot air for conveying the pulverized coal from mill to the furnace through coal carrying pipes. These fans are located at ‘O’ M level near the boiler. There are two to six fans per boiler.

Air Pre-heater: Air pre-heater transfer heat from flue gases to cold primary and / or secondary air by means of rotating heating surface elements (for rotary Air pre-heater). For regenerative type air pre-heaters, there exists a steam coil air pre-heater. These are located in the secondary pass of the furnace at a height of around ‘16’ M level. Each 210 MW unit is provided with two such air pre-heaters.

F.D.Fan: The forced draft fans (2 per unit – 50% capacity each) are designed for handling secondary air for the boiler. These fans are located at ‘O’ M level near the PA fan.

Wind Box: this act as distributing media for supplying secondary / excess air to the furnace for combustion. These are generally located on the left and right sides of the furnace while facing the chimney.

Scanner Fan: These fans, two per boiler (100% capacity), supply requisite air for scanner cooling.

Electrostatic precipitator: These are generally two plate type located between boiler and the chimney. The precipitator is arranged for horizontal gas flow and is constructed with welded steel casing.

ID Fans: These are two Induced Draft Fans (50% capacity each) per boiler located between the Electrostatic precipitator and the chimney. These fans are used for sucking flue gas from furnace.

Chimney: These are tall RCC structures with single / multiple flues chimneys (one flue per 210 MW units). The height of these chimneys varies depending on the location at considerations; anywhere between 120 m. to 220 m.

Seal Air Fan: These are used mainly for supplying seal air to the mill to prevent ingress of coal dust into gear box lubrication oil. There are two to six fans per boiler for 210 MW units.

Soot Blowers: Following two types of soot blowers, in requisite numbers, are provided:

1. Long retractable soot blowers. **2**. Wall blowers.

Superheated steam is tapped from superheater for the purpose of soot blowing.

Boiler Structural: The boiler structural are divided into two parts.

- Supporting structure.
- Galleries and Stairways.

Supporting Structures: Boiler supporting structure consists of a systematic arrangement of columns stiffened with horizontal beams and vertical diagonal bracing and comprise of low carbon steel material.

It is composed of 18 main columns and 12 auxiliary columns. The main columns support, the main boiler components viz. Drum, water wall membrane, panels, superheaters, reheters, economizers, air preheater, burners and galleries at various levels. The auxiliary columns support the boiler platforms and other ducts coming in that region.
Galleries and Stairways: Galleries and stairways around the combustion and heat recovery areas are provided for proper approach to the boiler. Stairways on both the side of boiler are provided. All the floors are covered with floor gratings for walkways and are tig welded to the structure.

Classification of Boiler, fundamental of boiler design, steam generation, principle of natural and assisted circulation.

Boiler a device used for generating (a) steam for power generation, process use or heating purposes and (b) hot water for heating purposes.

However, according to the Indian Boiler Act, 1923, a boiler is a closed pressure vessel with capacity exceeding 22.75 liters used for generating steam under pressure. It includes all the mountings fitted to such vessels, which remain wholly or partly under pressure when steam is shut off.

Boilers are classified on the basis of: -

1. Mode of circulation of working fluid.
2. Type of fuel.
3. Mode of firing.
4. Nature of heat source.
5. Nature of working fluid.
6. Position of the furnace.
7. Type of furnace.
8. Boiler size.
9. Materials of construction.
10. Shapes of tubes and their spatial position.
11. Content of the tubes.
12. Steam pressure.
13. Specific purpose of utilization.
14. General shape.
15. Manufacturers trade name.
16. Special features.

Some types of boilers according to the mode of classification are listed below:

Mode of classification	**T y p e**
Circulation	1. Natural Circulation Boiler 2. Forced Circulation
Tube shape and position (Depending on the form of tubular heating surface)	1. Straight tube boiler 2. Bent tube boiler.
Tube shape and position (Depending on the inclination of tubular heating surface)	1. Horizontal Boilers 2. Vertical Boilers 3. Inclined Boilers
Furnace position	1. Externally fired furnace 2. Internally fired furnace
Tube Contents	1. Fire tube boilers 2. Water tube boilers
Steam pressure	1. Lowe pressure Boilers 2. Power Boilers 3. Miniature Boilers
Mode of firing	1. Fired boilers 2. Non-fired boilers
Heat source	1. Fuel fired boiler 2. Waste heat boiler 3. Electrical powered boiler 4. Nuclear powered boilers
Nature of fuel	1. Coal fired 2. Gas fired 3. Oil fired 4. Wood fired 5. Bio gas fired
Type of Furnace	1. Dutch oven boiler 2. Open boiler 3. Scutch boiler 4. Screened boiler 5. Twin boiler

Boilers may be categorized into four general types: -

1. ***Steel Boilers.***
   a). Fire tube type.
   b). Water tube type.
   c). Shell type.

2. ***Cast Iron boilers.***
3. ***Special design boilers.***

4. ***Nuclear powered boilers.***

Water tube boilers may be further subdivided into :-

1. Horizontal straight tube type.
2. Bent tube type:
    a. Natural Circulation type
    b. Forced Circulation type.

Fundamental of Boiler design :

In a steam generating unit two distinct fundamental processes take place: -
Conversion of the potential energy of the fuel into thermal energy.
Transfer of this liberated thermal energy to the working fluid to generate steam for useful purpose.

This being the case, the basic task of a boiler designer is to maximize the output of these two processes simultaneously. And for that purpose he must design the layout of the entire heat-absorbing surface in such a manner that it will receive maximum available heat in the process of fuel combustion.

Following factors must be taken into account in the design consideration of a boiler:

1. Service requirements.
2. Load characteristics.
3. Fuel characteristics.
4. Mode of fuels burning.
5. Hydrodynamics of gas flow.
6. Feed water quality.
7. Furnace size, shape and material of construction.
8. Type of furnace bottom.
9. Boiler proper.
10. Boiler operation.
11. Capital investment.

A brief note on some of the above factors is listed below:-

Load Characteristic: The boiler designer should essentially consider the following load characteristics: -
1. Maximum load, normal load and minimum load.
2. Load factor.
3. Nature of load – constant or fluctuating.
4. Duration time of each load rate.

Fuel characteristics: - From these very characteristics, a boiler designer gets the knowledge of the heat value available from the fuel as well as its specific properties such as:-
a). Ash content and the percent of volatile matter.
b). Nature of ash and its fusion point.
c). The presence of corrosive agents as sulfur and vanadium that will dictate the flue gas exit temp as well as the material of construction of the heating surfaces of the boiler to avoid the problem of corrosion and slugging.

Fuel burning : It is the capacity of the fuel burning device that controls the rate of fuel input which in turn determines the furnace volume and its design specification.

Gas flow characteristic: The gas flow through the boiler is affected by the differential pressure between the combustion products in the furnace core and the flue gases at the boiler exit. This pressure difference, called draught (draft) may be affected by natural means or by mechanical means to supply the necessary primary and secondary air to sustain and control fuel combustion.

Feed water quality: The presence of dissolved solids and gases, suspended matter and organic contaminants in feed water cause corrosion, scaling, priming and foaming that effectively impair the performance of a boiler.

Feed water quality, together with other factors, influences the design of drum internals, steam separator and steam washer etc.

Furnace: The furnace volume must be sufficient to maintain the necessary heat release rate and further temperature while the combustion space should be sufficient to contain the flame so that it does not directly hit the water walls.

Furnace bottom design: For pulverized coal firing, the furnace bottom must be cone shaped to drop out all molten slag to be carried off mechanically, pneumatically or by water. The lack of proper furnace design for adequate ash removal may result in excessive slogging of water walls impair the heat transfer characteristic and performance of the boiler.

Boiler proper: The factors control the design of boiler proper are:-

- The operating pressure and temperature.
- The quality of steam – whether the steam required should be wet, dry or superheated. If wet steam is required, the designer may do away with the separators and superheaters.
- Layout of heating surface – The prime aim of boiler designer is to obtain the best disposal of heating absorbing surface within the limitations of space as dictated by the furnace and other components.
- Heating surface requirements – These depend upon the duty of the element heat exchangers such as primary evaporators, secondary evaporators, superheaters radiant and connective reheater, economizer and air preheater.
- Circulation of steam and water – Natural or forced.
- Provision of continuous blow drum.
- The capacity of Boiler drum.

Operation and Maintenance: Accessibility for operation, maintenance and repairing must be easy and quick to ensure higher operating efficiency and offset the long outage time.

Adequate provision must be made for:

- Soot blowing
- Tube cleaning – chemically / mechanically
- Wasting economiser and air preheater surfaces.

Automation should be injected wherever it leads to higher reliability and greater ease in boiler operation.

Capital investment : The following factors are involved in determining the overall capital investment in designing a boiler.

- Cost of equipment.
- Cost of fuel.
- Cost of labour and materials for operation, maintenance and repairing.
- Cost of the auxiliaries, e.g., cost of running pumps, fans, ash disposal systems, etc.
- Expected life of the equipment.

Steam Generation : Boiling and consequent steam generation is a quite familiar process. In brief, as we begin to heat water, it goes on absorbing heat at constant pressure and in evident by rise in the temperature. A stage reaches when water begins to boil and there is no rise in temperature. At this stage steam is formed, which continues to be so at the same temperature unless and until pressure changes. The first stage of heat has been absorbed as heat of water (known as sensible heat) & the second stage of heat expenditure is due to

the latent heat. Thus, thermodynamically speaking, boiling may be considered a special case of adding heat to the working substance in a constant pressure, constant temperature process.

As the pressure rises, latent heat decreases & a stage is reached at (221.06 bars), when the latent heat becomes zero, this pressure being termed as critical pressure.

Further, once the steam is formed & does not have any traces of water, i.e. dry saturated, we keep the pressure constant while heat is being added, the temperature of steam will begin to rise, the heat expended being known as superheat.

As the working pressure rises, the specific weight of water goes on decreasing while that of steam goes on rising till at critical pressure it becomes equal both for steam and water.

Because of the specific weight, differential between water and steam at a given pressure, there exists a differential head, which even a pretty long range of pressure provides a good means for circulation during steam generation. Depending upon working pressure, i.e. below critical or above critical, the steam generators are designated as sub-critical or super – critical.

Whereas, for a greater part of the range in sub-critical pressure it is possible to have natural circulation during evaporation, but above super critical pressures, circulation is forced one. In the higher sub-critical pressure range also due to the reason of economy, forced or assisted circulation may be employed.

Types of boiling :

It is essential to have a temperature gradient between the products of combustion & the fluid, in order to have heat transfer from the former to the later. The temperature gradient for a given flux apart from the fluid flow and conductivity of metal will depend upon external and internal deposits on the tube. The change from liquid to vapour takes place both at the solid liquid interface, as at the inside tube surface of a water tube boiler & at the liquid vapour inter face, as with the water surrounding the steam bubbles. There are two distinct viz. ‘Nucleate’ & ‘Film’ type of boiling, based upon the modes of formation & release of steam bubbles. The details of the two types are given in the following sub-sections.

Nucleate Boiling : As the heat flux increases, the water temperature near the surface increases and reaches saturation temperature. At this point a change from liquid to vapour occurs locally. But since the bulk of water does not reach saturation temperature the steam bubbles collapse giving up their latent heat to raise the temperature of water. When the bulk of water reaches saturation temperature the bubbles do not collapse. This condition is known as Nucleate boiling. Nucleate boiling regimes are characterized by high heat transfer co-efficient.

FILM BOILING : Beyond nucleate boiling region (i.e. at still higher heat fluxes) the bubbles collapses to form a film of superheated steam over part of all the heating surfaces. This condition is known as film boiling. The point, beyond which film boiling occurs, is known as departure from Nucleate Boiling (DNB).

Circulation : The term circulation generally with drum type of boilers applies to the movement of fluid from the drum to the combustion zone and back to the drum. The feed water to the drum in any case reaches the drum from the boiler feed pump via the economiser. The water leaves the drum through the down comers at a temperature slightly below saturation temperature. The flow through the furnace wall is at saturation temperature. Heat absorbed in water wall is latent heat of vapourisation creating a mixture of steam and water.

Types of circulation system :

1. Natural circulation.
2. Positive Circulation.

Natural Circulation: - Water delivered to a steam generator from feed heater is at a temperature well below the saturation value corresponding to that pressure. Entering first, the economizer, it is heated to about 30 to 40 ^{o}C below saturation temperature. From economizer the water enters the drum and thus joins the circulation system. Water entering the drum flows down through the down comer and enters ring header at the bottom. In the water walls a part of water is converted to steam and the mixture flows back to the drum. In the drum, the steam is separated, and sent to superheater for superheating and then sent to HP Turbine. Remaining water mixer with the incoming water from the economizer and the cycle is repeated.

The circulation, in this case, takes place on the thermo-siphon principle. The down comers contain relatively cold water, whereas the riser tubes contain a steam water mixture, whose density is comparatively less. This density difference is the driving force for the mixture. Circulation takes place at such a rate that the driving force and frictional resistance in water wall are balanced.

As the pressure increases, the difference in density between water and steam reduces. Thus the hydrostatic head available will not be able to overcome the frictional resistance for a flow corresponding to the minimum requirement of cooling of water wall tubes. Natural circulation is limited to boiler with drum operating pressure around 175 kg/cm^2

Positive Circulation : In this type, use of pumps is made for movement of fluid through the combustion zone or complete heat transfer circuits. This type of circulation is further divided into:
i). Assisted Circulation.
ii). Forced Circulation.

Assisted Circulation: The term is generally used in case of boilers having drums and working below critical pressures. Circulating water pumps are used in between the bottom headers of down comers and risers to overcome frictional losses and the consequent movement of water and water steam mixture.

Forced Circulation : The term is generally used for movement of fluid in boilers working above critical pressures. These boilers are of once through type. The pump forces movement of fluid through all the heating zones viz. Economizers, tubes in combustion zone & superheaters. A small separating or mixing vessel may be provided for removal of moisture from steam and pumping back to the circuit .

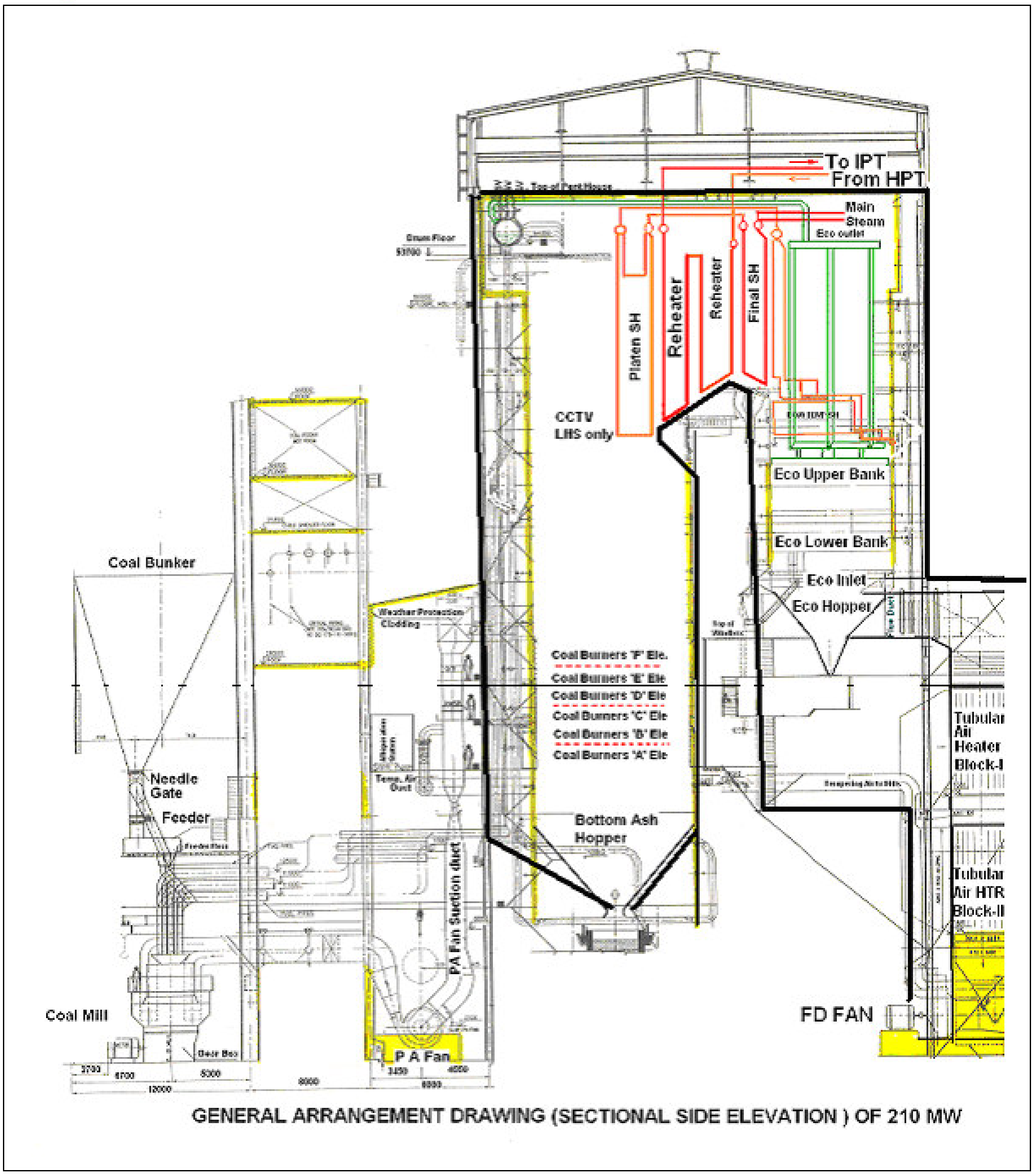
Circulation Ratio: It is essential to maintain a certain amount of flow of water to the steam generating circuits in commensurate with the amount of steam generated from them, in order to prevent ‘Burn-outs’ and ‘On-load corrosion’. The ratio by weight of the water fed to the steam generating circuits to the steam actually generated (kg water : kg steam) is called ‘Circulation Ratio’. Taking an example for a unit period of time 5 kg of water is admitted to risers (which will get converted into mixture of water and steam during its passage through the furnace) and 1 kg of steam is taken out of the drum, the value of circulation ratio will be five. The remaining 4 kg of water will be recirculated in the system. To compensate for 1 kg of steam taken out, 1 kg of water will have to be added to the drum, which will enter the risers along with the water under recirculation.

Circulation Ratio to be adopted for a particular design will be influenced by the operating pressure and the available head. The values of these parameters will decide the circulation head available to produce the driving force available.

The circulation ratio for various types of boilers is:-

i). Utility Boiler : 6 to 9.
ii). Industrial Boiler : 8 to 30.

Higher circulation provides higher thermal inertia and faster response essential for industrial boilers.



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Constructional details of heating surface arrangement of furnace; Super heater; Reheaters; Economizers; Boiler drum intervals. Various types of air pre heater; and their constructional details; Flue gas path system.

Introduction:- In a boiler water is continuously circulated and drawn out as super heated steam. The process of conversion from water to steam by addition of sensible heat. latent heat and super heat is done by

circulating through various heating surfaces. The path followed for this conversion is called water and steam circuit along with flue gas path.

Water Circuit:- Feed water is supplied to economizer inlet header via feed regulating station and check valve. The feed water flow is upward through the economizer coils that are counter flow to the hot flue gases. After feed water is collected by Economizer intermediate header it passes through Economizer hanger tubes to reach top economizer outlet header. The water from economizer outlet header will go to drum through economizer connecting links to drum. Water from drum comes to bottom water wall ring header through 6 nos. vertical down-comers. From ring headers it rises through front side and rear water wall panels and absorb radiant heat and the resulting mixture of water and steam will reach top water wall headers above roof. The mixture will be discharged into drum by riser pipes. Steam is separated from the mixture inside the drum by drum internals equipments.

Steam Circuit:- Saturated steam leaves the drum and enters the SH radiant roof inlet header (SHH-1) through SH connecting pipes. The path between the roof inlet (SHH-1) and outlet (SHH-2) headers forms the front steam cooled roof above the furnace.

The steam leaving the roof outlet header (SHH-2) enters the rear pass side walls through rear pass side wall inlet header (SHH-3L & 3R).

Leaving rear side wall inlet header (SHH-3L & 3R) the steam flows down through the rear side wall into a U shaped header at the base of rear pass. This is called rear pass sub outlet header. Fin welded panels connected to SHH (4L & 4R) feeds the steam to front inlet header (SHH-5) via elbow connection.

SH rear pass front inlet header (SHH-5) feeds the steam to junction header SHH-7 via rear pass front wall. It also feeds the horizontal pass extended. Side wall through connecting tube on each side. The connection tube between rear pass front inlet header (SHH-5) and extended side wall inlet header (SHH-6) are called SH hanger tube. The panels from SHH-6 cover the bottom and side portions of extended region and connected to a separate header at top on either side (SHH-3AL, 3AR). The steam from these headers reaches junction header (SHH-7) through connecting tubes.

The rear pass junction header (SHH-7) supplies steam to rear pass roof tubes. These tubes from the steam cooled rear roof and steam cooled rear wall in the forma of tin welded panels ending at the rear pass rear wall outlet header (SHH-9).

Also a portion of steam from SHH-4L & 4R on either side enter SHH-8 through elbow connection and goes up to rear wall outlet header (SHH-9).

Leaving the rear pass rear wall outlet header (SHH-9) the steam flow upward once again through a series of terminal tubes to the rear horizontal SH inlet header. From the rear horizontal super heater inlet header, steam passes up through horizontal superheater or low temperature super heater. The outlet of the low temperature super heater forms the terminal tubes or hanger tubes and they terminate in rear horizontal super heater outlet header (SHH-10).

Temperature control feature called (De super heater) are placed in between LTSH outlet header (SHH-10) and platen SH inlet header (SHH-11). There are two DESHS. The function of the DESH is to reduce steam temperature when necessary and maintain the SH outlet temperature at the design value during operation. The DESH cool off the steam by spraying feed water when called upon to do so.

After leaving the DESH, the steam now travels on its way to the vertical PSH inlet header (SHH-11). The inlet header supplies steam to the platen SH coil. After passing through vertical platen SH coil, the steam enters the vertical PSH outlet header (SHH-12).

From platen SH outlet header (SHH-12) steam enters the final SH inlet header (shh-13) through two connecting pipes. In between these two headers 2nd DESH (2) are placed. SHH –13 will allow the steam to pass through final SH coil to reach final SH outlet header SHH-14. The main steam line will further carry the steam to HP turbine from either side of SHH-14.

The cold reheat steam flows from the HPT to reheater inlet header. Serving the RH vertical spaced Coils. In these coils steam is reheated up to design value and sent to IPT through hot reheat line from both RH outlet header. An emergency reheater DESH Unit has been provided at the inlet of RH.

Arrangement of heating surface:

Generally heating surfaces can be arranged either in line or staggered. Staggered arrangement require less surface for same duty but draft losses will be more and on load cleaning of surface will not be as effective as in line arrangement. So, selection of any one of them depends on the fouling with fuel characteristics operating cost of draft loss, cost of tube material etc.

The surfaces can be designed to place in such a way that the flow direction of flue gas and steam is parallel or opposite. Counter flow arrangement has the advantage of minimum surface but the metal temperature, as the leaving section is high compared to parallel flow. Hence the counter flow is used in most of the cases except in final section where the metal temperature limitation calls for parallel flow.

The platen SH is placed in the flue gas path ahead of final SH to transfer heat by radiation and connection in some proportion such that the outlet steam temperature can be maintained fairly constant at all loads.

Most of the RH surface is placed in hotter zone between PSH and final SH so that the surface requirement is kept minimum to reduce the pressure drop in steam to keep the cycle efficiency maximum.

The unit is designed for a maximum continuous evaporation of 690 Ton / hr. at a pressure of 149 kg/cm^2 and a steam temperature of 537 ^{o}C with reheat temperature 537 ^{o}C. The feed water temperature at this load being – 247 ^{o}C.

F U R N A C E:

It is a tall rectangular chamber surrounded by water tubes wall on the four sides and on top. Furnace is designed for efficient and complete combustion. Also its design details and proportions are considerable importance to the successful operation of the boiler.

Combustion of fuel takes place inside the furnace. Major factors that assist for efficient combustion are: – Time of residence (fuel) inside the furnace.

Turbulence which causes rapid mixing between fuel & air.
Furnace design is influenced by the following factors.
The choice of fuel will considerably influence the size of the furnace. The coal burning steam generators because of the ash produced have larger furnace.

Fuel	Width	Depth	Height
Gas	W	D	H
Oil	1.06 W	1.05D	1.2 H
Coal	1.12 W	1.10D	1.5 H

H = 43129 M
D = 10.592 M
W = 13..686 M

Volume - 5202 M^3

Front wall → 618 sqm.
Side wall → 757 sqm.
Rear Wall → 620 sqm.
Roof Wall → 122 sqm.
Total → 2117 sqm.(EPRS)

Allowable heat Loading:

.Surface – This is related to the gas temp. Leaving the furnace.
Plan area – This is related to the maximum temp. of product of combustion and maximum

localise heat absorption rate.
Volumetric – The volume should be such that full combustion completed in the furnace.
EPRC heat loading (safe values) – 200,000 – 325,000 $Kcal/hr/m^2$
Plan area heat loading(safe value) – 3-4 x 10^6 $Kcal/hr/m^2$
Volumetric heat loading (safe value) – 130 – 300 x 10^3 $Kcal/hr/m^3$

Burner clearance: Sufficient height between the top row or fuel nozzles and furnace outlet must be provided to obtain proper furnace retention time (2.5 sec.)

Retention time :
Furnace residence time – Time taken by a fuel particle to leave the burner and up to full combustion of the particle is known as residence time.
Height of burner zone – 8 meter.

FURNACE WALL:
Furnace enclosures membrane wall construction is adopted. They are called fusion welded panels in which a number of tubes are joined together by a process of fusion welding. The fusion welded panels have been built with tube size of 63.5 mm OD 6.3 mm thickness and spacing between two adjacent tubes 76.2 mm and the panels are made in widths on length is because of transportation.
Front and rear wall contains – 181 tubes on 13.686-m length.
(Rear water wall tube 181 Nos. = 124 screen tube + 37 hanger tube + 2x10 extended side wall).
Side wall contains – 130 tubes on 10.592 m length.

Membrane wall construction offers following advantages:

1). Pressurized furnace is possible with the related advantages of: –
- Better load response with similar combustion control.
- Quicker starting and stopping.
- Forced draft fan handle less air.

2). Heat transfer is better.
3). Erection is made easy and quick.
4). Gas tight enclosure.
5). Less insulation weight.

Advantage of water cooled furnace:
- Not only combustion but also heat transfer is taking place simultaneously.
- Due to heat transfer in the furnace, temp. of the flue gas leaving the furnace is reduced to the acceptable level of the super heating surface.
- Higher heat loading in the furnace is possible as heat is being simultaneously removed by heat transfer and hence economy in surfacing.

No. of riser tube – 118 with dia of 127 mm
Water wall tube material – Carbon steel; (SA 120 Gr. AL).

Mode of heat transfer:
Radiation: Through the space in furnace.
Convection: Through the currents of hot gas.
Conduction: Through the metals of the tube.

Boiler Circulation System:
Three system of circulation adopted in boiler are –
Natural Circulation.
Assisted circulation. (Forced Circulation)
Combined circulation. –do-.

<u>Natural Circulation</u>: When the flow is established due to density difference of water between down comer and risers, as riser tubes contain water and steam mixture. This circulation establishes without any external influence it is called natural circulation.

<u>Assisted circulation</u>: As operating pressure increases the density difference between down comer and riser decrease. Beyond certain operating pressure a situation reaches where the available hydro-static head is not able to overcome the frictional resistance for a flow corresponding to the minimum requirements of cooling water wall tubes. Therefore extra driving force is required to assist the circulation.
Natural circulation is limited to Boiler with drum operating pressure - **175 kg/cm^2 or less**

Assisted circulation - **175** kg/cm^2 or less to **200** kg/cm^2
Beyond critical pressure phase transformation is absent hence once through system is adopted. > 240 kg/cm^2

<u>Circulation ratio</u> – No of circulation required to convert one kg of water to one kg of steam. Physical significance of circulating ratio is that how many times a water particle circulates in steam generating circuit before getting converted into steam **(6 to 8).**

***<u>Type of Furnace</u>*:** According to the mode of bottom ash collection furnace are classified in the following three ways: –

1). Dry bottom furnace. 2). Oil fired furnace & 3). Wet bottom furnace.

<u>Dry bottom furnace</u>: Selected for coal of non-slagging type Fusion temperature of the ash produced by combustion will be more than the temperature encountered in the furnace. The ash fusion temperature is between 1200 ^{o}C to 1350 ^{o}C and furnace temperature is 1100 ^{o}C. Normally a maximum of 20% total ash may be collected as slag from bottom of furnace. The rest of the ash is carried away along with flue gas.

If slagging type coal is used in dry bottom furnace, slag will fuse and deposit in the heat transfer surfaces of furnace SH & RH where removal may pose problem.

Hopper at the bottom is formed by slopping the front and rear water walls, thus the amount of brick work is reduced and hence maintenance. By this arrangement loss of efficiency due to evaporation of water from hopper is also effectively reduced. Most of Indian coals contain high amount of silica in ash and hence are best suited for Indian coals. In addition, loss of efficiency due to sensible heat in the molten ash of wet bottom furnace which increases with ash content also favours use of dry bottom furnace for high ash content coals.

<u>Expansion of furnace:</u>
Provision for free expansion of furnace tubes is vital and it is normal for tube walls to be entirely suspended from the top of the structural member so that all expansion is taken in a down ward direction. 48 meter high furnace will have roughly 208 mm expansion due to temperature change alone during boiler operation.

Downward expansion of the furnace walls is absorbed by the ash hopper water seal or trough seal. Sidewise expansion of the furnace walls is absorbed by Buck stay.

<u>Function of trough seal:</u>
To prevent the ingress of air inside the furnace as furnace is in negative pressure.
It absorbs the furnace thermal expansion (~208 mm) which is in hanging condition.
It allows to pass away the flue gas / air if in any case boiler becomes highly pressurized so it is a safety device of S/H & R/H coil.

<u>Boiler Drum:</u>
Function:-1) Separate steam from water.

2) Act as water storage tank and proper place for water supply so that water can circulate.
3) Proper place for Boiler water treatment so that boiler water quality can maintained.
4) Any necessary Blow down for reduction of boiler water concentration (silica and sludge) is usually done from the drum.

Drum metal – SA299 (C.S.)
Sustain temperature – 354 ^oC
Drum internal dia – 1778 mm.
Shell thickness – Higher thickness – 180 mm where Riser tubes are connected.
Lower thickness - 145 mm Where down comer and Eco inlet are connected.
Weight – 113 ton.; Length – 14.94 m.
No. of down comer – 6 with vortex Breaker. ϕ 406.4 mm
Design pressure – 177 KSG and working pressure – 166 KSG.
Normal level – 254 mm or 10” below centre line.
Minimum level – 349 mm below centre line.
Elevation – 55m from ground.

Drum internal:

- Primary separator or cyclone separator (2 x 29).
- Secondary separator or corrugated sheet or secondary scrubber.
- 60 to 70 sheet over each cyclone separator.
- Final separator or screen dryers – 39 no.
- Drum internals are non-pressure bearing parts and made of carbon steel of medium strength and capable of withstanding operation up to 354 ^oC in the medium steam and water.

Separation process:
This arrangement consists of a primary axial flow turbo separator along the length of the drum. A plate type corrugated sheet secondary separator at the outlet of the turbo separator and screen drier boxes prior to the entry to steam outlet nozzles.

The centrifugal action is imparted by the spinner blades and separation takes place by centrifugal action. The secondary separator is plate type corrugated sheet arranged so as to have horizontal flow in a zigzag path and throws the heavier water particles. The drier boxes are wire mesh boxes with more wetting surface. The gravity separation takes place in the space between secondary separator and screen driers.

Economizer :
The purpose of the economizer is to preheat the boiler feed water before it is introduced in to the steam drum and to recover some of the heat from the flue gases leaving the boiler. The economizer absorbs heat from the flue gas and adds it mainly as sensible heat to feed water. The temperature of feed water is kept just below the saturation temperature in case of non-steaming economizers. The outlet temperature should preferably by 35 ^{o} lower than saturation point.

Location: The economizer is located in rear gas pass below the rear horizontal SH and ahead of APH. Counter flow arrangement is selected so that heating surface requirement is kept minimum for the same temperature drop in the flue gas. Heating surface is 5719 m^2 . Economizer coils are designed for horizontal placement, which facilitate draining of the coil.
Economizer is divided into two sections but features are the same each cases. Each section is composed of a number of parallel tube circuits. All these economizer tube circuits are supported from the bottom by means of three sets of plate hanger.

Mode of heat transfer – convection
Economizer upper and lower bank consists of 162 x 2 = 324 Nos. tube.
OD and thickness of each tube – 44.5 mm x 4.5 mm.
Tube materials – Carbon steel (SA210 Gr. A1)

Economizer feed pipe and inlet outlet header – Carbon steel (SA106 Gr. C)
Design temperature – 315 ^{o}C for tube materials.
330 ^{o}C for intermediate header.
Flue gas inlet and outlet temperature – 462 ^{o}C and 370 ^{o}C
Feed water inlet and outlet temperature – 247 ^{o}C and 305 ^{o}C.
The inlet feed water temperature should not be less than 140 ^{o}C from low temperature erosion point of view.

Economizer Recirculation line:

From down comer to economizer inlet after check valve a water recirculating connection is the eco-recirculation line.

To give adequate circulation from boiler drum during the periods when feed flow is absent. This prevents economizer tubes from "boiling out" and "over heating" such as pressure rising.

Function of Economizer:

- It increases the heat economy of flue gas.
- To reduce the furnace load.
- To reduce the circulation ratio.
- It increases the boiler efficiency.

Super heater:

These heating surface are in the form of coils which are made by bending the tubes in conditions. The super heater is composed of three sections.

!. Platen SH – Total heating surface – 810 m^2.
Material – SA213T22 (2 ¼/Cr. And 1 Mo)
¾% of the heating surface is made counter flow while the remaining ¼ acts in parallel flow.
Mode of heat transfer – Mainly radiation (85%).
Convection (15%).
20 assembly, 10 element with tube dia ϕ51 mm.
Distance between two assembly 685 mm and end spacing – 419 mm.

2. Final SH – Total heating surface – 823 m^2.
Material – SA213 T P 347H (Stainless steel).
Mode of heat transfer – Convection.
119 assembly 4 element with dia 44.5 mm thickness 5.6 to 8.8 mm.
Distance between two assemblies – 114.3 mm. & End space – 190.5 mm.
L T S H – Total heating surface – 6490 m^2.
Material – SA 210 A_1 – 425 ^{o}C
- SA 210 T_1 - 450 ^{o}C ½ Mo
SA 213 T_{11} – 495 ^{o}C 1 ½ Cr. ½ Mo Alloy steel.
Mode of heat transfer - convection
120 no. coils of 4 tube circuit.
Diameter – 44.5 x 4.5 (thickness).

Function of S.H:

- Basic thermodynamic gain in efficiency.
- Dries the steam before it enters the turbine.
- It has less tendency to condense in the last stages of turbine.

The platen section is located directly above the furnace which can view the flame at the exist of the furnace in front of the furnace water wall notch. As the radiant surfaces are located in high temperature region, they

are widely pitched to reduce the velocity of the gas and bridging the surfaces by the ash and they are arranged in line with least transverse pitch. The final super heater is located in back of the screen wall tubes. The horizontal section of SH is located in the rear gas pass above economizer with the advantage of draining. The steam cooled wall sections from the side front and rear walls and roof of the vertical gas pass. The combination of convective and radiant super heater is generally used in all boilers to give flat super heat curves over wide ranges in load.

Reheaters :

The fundamental considerations governing super heater design apply also to reheater design. The reheat is composed of two stages the front and rear pendant vertical spaced sections. The rear pendant vertical spaced section is located above the furnace notch between WW screen and rear wall hanger tubes. The front pendant vertical spaced section is located between the rear WW hanger tubes and the super heater platen section. The outside diameter of reheater tubes will be larger than of superheater tubes as more volume is to flow through reheaters operating at low pressure.

Function of RH:

- To raise the temperature of the steam from which part of energy has already been extracted by HPT. Thus reduced moisture content in last stage of turbine (10-12%).
- To reduce the pressure drop in steam to keep the cycle efficiency maximum.

Total heating surface – 2630 m^2
Material – SA213T22 and SA213T91

Mode of heat transfer – convection and radiation.
59 assembly and 6 element; diameter of tube 54 mm with thickness 6.3 mm to 8 mm.

Air preheater:

APH is used to cool the exit flue gases in the heating of air supplied for the combustion of fuel. Flue gas inlet and outlet temperature – 370 ^oC / 138 ^oC

Function:

- To save the fuel by pre heating of air for same energy input to the furnace.
- To increase the efficiency of boiler, approximately proportional to the air temp. rise in APH. (For every 20 ^oC drop in the gas exit temperature the boiler efficiency increases by at least 1%).

Air is pre heated for the following advantages:

- To dry the coal in pulverizer.
- Stability of combustion.
- Intensified and improved combustion.
- Less unburned fuel particle in flue gas.

Type of APH: 1). Recuperative APH.
a). Tubular heater b). Plate type heater c). Steam coil heater.
2). Regenerative APH
a). Rothemuhle heater b). Lyungstrom heater.

Regenerative APH:

Regenerative APH known as storage type heat exchanger called matrix, which is alternately exposed to the hot and cold fluids. When the hot flue gases flow through the matrix in first half of cycle, the matrix gets heated and the gas is cooled. In the next half of the cycle when air flows through the matrix air gets heated and the matrix cooled. The heat transfer from gas to air is thus periodic the amount depending on the Nos. of heating / cooling cycle executed / sec. Thus gas and air both flows through the steel sheet and corrugated sheets.
Matrix or sheet – Mild steel or carbon steel.

Advantage: -

- High efficiency and low maintenance cost.
- Rotary APH are compact heat exchanger with a large heat transfer surface being accumulated in small volume.
-

Tubular Air preheated: Heat is directly transferred from the hot gases to the air across the heat-exchanging surface. Tubular units are counter flow shell and tube heat exchangers in which the hot gases flow inside the vertical straight tubes and air flow out side.

Construction - Tube materials – carbon steel.
63.5 mm (OD) x 2.08 mm (thickness) x 7 mtr. (height).
Total Nos. of tube – 28788. (4799 / Pass / Bank).

Tubular air preheater consists of a number of tubes expanded at each and into tube plates to form banks. The tubes are enclosed in a steel casing which forms the passage for air flow "C" type expansion bellow is provided between the casing and top tube sheet to care of the difference in expansion of tubes and casing. Another 'S' type expansion bellow is provided between the air preheater block and the gas inlet duct which takes care of the block expansion.

If the tube length is more middle tube sheet will be provided to minimize tube vibration. If necessary baffle plate will be provided along the air flow to minimize the acoustic vibration. The supporting frame welded to the bottom tube sheet is to be rested on the supporting beam. Depending on the erosive nature of ash in flue gas tube extension with castable refractory will be provided at gas inlet.

Each air preheater block will be manufactured in one or more modules. These modules shall be assembled and seal welded at site.

Guide vanes shall be provided particularly in the air ducts to ensure even distribution of air over the cross section of the air preheater.

Tubular APH is used though Regenerative APH having higher efficiency than Recuperative air pre-header due to following reason.

- Leakage of air into gas and gas to air due to entertainment of rotary action.
- Flow opening being plugged by ash.
- Large pressure drops for both gas and air.

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21

COMBUSTION CHAMBER DETAILS - WINDBOX & BURNER ARRANGEMENT

In the furnace, chemical energy of fuel is converted into the of combustion products as pulverised fuel is burned in suspension in the furnace space. Combustion products give up part of their heat by radiation to water walls. Thus they leave the furnace at a safe temperature, which will not cause clinkering of the subsequent convective heating surface.

Factors important for combustion = 3 T :

1) TIME = Residence time of fuel
2) TEMPERATURE = Furnace gas temp. (Must be > fuel ignition temp.)
3) TURBULENCE

1) => Furnace volume is large enough to give the mix. time to complete combustion. (Height of boiler is governed by the residence time of fuel) .

2) => Fuel + air mixture maintained at > ignition temp.
3) => Adequate quantity of air supply to fuel, so that O2 + fuel are thoroughly mixed.

Amount of excess air reqd. is dependent on load. Furnace cross-section area & design must support full load gas flow rate at acceptable velocities. However, when load is decreased, gas flow rates and associated velocities drop off & proper mixing of the fuel with combustion air becomes difficult. Therefore additional air is introduced as load is decreased to maintain effective combustion.

Secondary Air velocity (maintained by proper WB to furnace dp)------> Air-Fuel mix. vel.-----> TURBULENCE

Dimension of furnace are dependent upon = 1) proper residence time
2) Avoidance of high temperature
3) Proper flue gas velocity

Time required. for complete combustion also depends upon particle size of the combustible - fineness of the fuel provided other conditions are met. Combustion is a two-stage process involving ----

* Physical contact of combustible with O_2 .
* Chemical combustion of the two after contact.

Once ignition temp. is attained -- chemical process is instantaneous but cannot proceed until physical contact has been made, i.e. rate of combustion is controlled by the rate at which contact is made between O2 & the combustibles.

FURNACE

FURNACE DUTY :

The modern furnace is designed to have the following:

- A surface area sufficient to reduce the temperature of the flue gases to a level acceptable to Superheater requirements.
- Adequate water circulation in the furnace tubes. This means a tube diameter, which has a friction pressure
- Drop, which allows sufficient fluid flow to avoid overheating. Natural circulation boilers have larger diameter tubes (with similar friction drops) than pump assisted circulated boilers because of the reduced driving force.
- A dimension in the path of the burner sufficient to avoid flame impingement on opposite wall, But not so excessive that the heat transfer is reduced.
- A width sufficient to accommodate all burners on acceptable pitching to avoid flame impingement on side & division walls, and interference of one flame with another.
- Overall dimensions and shape sufficient to ensure a gas path which will fill the furnace provide optimum absorption to all parts and a fuel - ash particle residence time sufficient to ensure burn out.
- For a coal fired boiler the Furnace together with the Platen must have sufficient area to cool the gases below the ash softening temperature, This is to ensure that deposits outside the furnace envelope are solidified.

NOX Reduction:

Emission standards / main NOX reducing parameters are met by following measures:

- Reduction of SA qty. injected through the fuel nozzles.
- Diversion of the SA injected through the auxiliary SA nozzles towards the furnace walls.
- Injection of the remaining SA through ports above the top fuel nozzles on the original firing circle (over fire air)

DRY BOTTOM Furnace:

Slag is removed in the solid state. Characterised by the provision of a Dry - bottom hopper that is formed in the lower portion of the furnace by inclining the front and rear water walls at an angle of 50 to 60 deg. so that the distance between them decreases at the bottom. The Dry Bottom Hopper intensively cools the furnace gases in the furnace bottom, so that molten slag particles which enter this zone are cooled quickly, solidify and fall along the hopper sides into a slag pit / bath. The water bath also serves as the hydraulic seal preventing the suction of cold air from beneath into the furnace.

BURNERS & ARRANGEMENT:

The desired intensity and completeness of pulverised fuel combustion in the furnace space can be achieved through proper supply and intermixing of pulverised fuel with Secondary Air in a burner assembly. Burners do not ignite fuel. Their function is to prepare two individual flows, a dust-air mix. and Secondary Air (SA) , for ignition and active burning in the furnace space . For this purpose hot air and fuel air are introduced into furnace space at different speeds and with different degrees of turbulisation.

Two main types of burners = (a) Straight flow burner * & (b) Turbulent / Vortex burner.

In a Vortex burner, fuel-air mix. & Sec. Air are fed as whirled (turbulised) jets which form a cone shaped expanding flame in the furnace space.

In Straight Flow burners, the fuel-air mix. and Sec. Air is blown in parallel jets. Their intermixing in the furnace is ensured mainly by an appropriate arrangement of burners on the furnace walls and by providing a particular aerodynamic pattern of jets in the furnace space. Burners of this type turbulise the air flow less substantially than do turbulent burners and produce a long ranging jet with low expansion angle and weak intermixing of the Primary & Secondary flow. Efficient combustion is achieved by making the jets from various burners interact with one another in the furnace space. Straight flow burners may be fixed or tilt-able which facilitates combustion control.

Burner Arrangement: Burners are arranged on the walls or corners of a furnace so as to ensure complete combustion in the flame core as possible, provide favourable conditions for the removal of slag from the furnace (dry or molten), and avoid clinkering of the furnace walls. The optimal arrangement of burners is found by properly considering there and characteristics.

A burner arrangement with corner burners and flame jets directed tangentially to an imaginary circle in the furnace centre -- is advantageously characterized by the uniform distribution of heat flows between the furnace walls and by the low probability of clinkering of the walls since they are in contact with furnace gases, which have already been cooled appreciably.

Tilting burners are only employed in corner firing, are positioned in corners of the combustion chamber with the burners firing slightly from the chamber wall towards an imaginary circle to which the flame path is tangential. This results in a rotating fireball. In moving the fireball up or down by altering the burner tilts in up & down, the heat transfer in the furnace chamber can be altered. The usual tilt range is 30 degree. With the fireball in the bottom of the furnace, the heat transfer to combustion chamber will increase because the surface area seen by the combustion product is at a maximum. Conversely with the tilt in an upward direction and the fireball at the top of the furnace, the heat transfer is at a minimum.

1. FUELS

A coal-fired unit incorporates oil burners to a capacity of 25% of boiler load for the following reasons:

a) To provide necessary ignition energy to light up coal burner.
b) To stabilize the coal flame at low boiler / burner loads.
c) As a safe start-up fuel and for controlled heat input during light off.

HFO, LFO

HFO is recommended as a start-up fuel in a cold boiler if steam is available for following services, otherwise LFO is the fuel recommended as a start-up fuel in a cold boiler with air atomizing media:

- For atomizing the HFO at the oil gun.
- For tank heating, main heating and heat tracing of HFO.
- To preheat the combustion air at the steam coil Air Pre-Heater (APH) and to warm up the main air heater (this reduces $SO2$ condensation). The four furnace corners are designated as 1 , 2 , 3 & 4 in clockwise direction looking from top , and counting front water-wall left corner as ' 1 '.Each pair of coal nozzle elevation is served by one elevation of oil burners located in between the auxiliary air nozzles . With 6 mills, 12 oil guns are arranged in 3 elevations at auxiliary air nozzles AB, CD, EF. Each oil gun is associated with an igniter arranged at the side.

2. BURNER ARRANGEMENT

In a tangentially fired boiler, four tall wind boxes (combustion air boxes) are arranged one at each corner of the furnace. The coal burners or coal nozzles are located at different levels or elevations of the wind boxes. The number of coal nozzle elevations is equivalent to the number of coal mills. The same

elevations of coal nozzles at 4 corners are fed from a single coal mill.
The coal nozzles are sandwiched between air nozzles or compartments, i.e. air nozzles are arranged between coal nozzles one below the bottom end coal nozzle and one above the top coal nozzle. If there is ‘n ‘number of coal nozzles per corner there will be ' n+1 ' number of air nozzles per corner.
The coal - fuel and combustion air streams from these nozzles or compartments are directed tangential to an imaginary circle at the centre of the furnace. This creates a turbulent vortex motion of the fuel, air and hot gases which promotes mixing, ignition energy availability and thus combustion efficiency.
The coal and air nozzles are tiltable 30 about horizontal, in unison at all elevation and corners. This shifts the flame zone across the furnace height for the purpose of steam temperature control.
The air nozzles in between the coal nozzles are termed as AUXILIARY Air nozzles and the topmost and bottom most air nozzles as END Air nozzles.
The coal nozzle elevations are designated as A, B, C, D, and E & F from bottom to top, the bottom end air nozzles as AA and the top end air nozzles as FF. The aux. air nozzles are designated by the adjacent coal nozzles, like AB, BC, CD, DE and EF from bottom to top.

3. COMBUSTION AIR DISTRIBUTION

Of the total combustion air, a portion is supplied by Primary air fans that go to coal mill for drying & pulverizing the coal and carrying it to coal nozzles. This PA flow quantity is decided by the coal mill load & the no. of coal mills in service. The PA flow rate is controlled at the air inlet to the individual mills by primary air dampers - PAD
The balance of the combustion air, referred as Secondary Air, is provided from Forced Draft fans. A portion of SA (normally 30% -40%) called ' Fuel Air ', is admitted immediately around the coal fuel nozzles (annular space around the casting insert) in to the furnace. The rest of the SA called ' Aux. Air ‘is admitted through the aux. air nozzles & end air nozzles.
The quantity of SA (fuel air + aux. air) is dictated by boiler load & controlled by FD fan vane regulation.
The proportioning of air flow between the various coal fuel nozzles & aux. air nozzles is done based on boiler load , individual burner load and the coal/oil burners in service , by a series of air dampers. Each of the coal fuel nozzles and aux. & end air nozzles are provided with a LOUVER type regulating damper at the air entry to individual nozzle.
In the units with 6 mills, there will be 6 fuel air dampers, 5 auxiliary air dampers and 2 end air dampers per corner.
Each damper is driven by an ' air cylinder positioned ' set, which receives signal from SADC system. The damper regulates on elevation basis, in unison at all corners.

FURNACE PURGE

Traces of unburnt fuel air mixture might have been left inside the furnace; some fuel (particularly gas or lighter fuels) might have entered the furnace through leakage of valves during shutdown of the boiler.
Lighting of a furnace with such fuel and air accumulation leads to a high rate of burning, furnace pressurisation & to explosions at the worst. This is avoided by the ' Furnace Purge ' operation, during which 30% of total air flow is maintained for 5 minutes to clear off such fuel accumulation and fill the furnace with clean air, before lighting up.
During ' Purge ' all the elevations of aux. & end air dampers are opened to have a uniform and thorough purging across the furnace volume.

BOILER LOW LOAD OPERATION

During initial operations up to about 30% boiler loading (and also during furnace purge) all the aux. & end air dampers modulate to maintain a pre-determined (approx. 40 mm wc) set point differential pressure between the windbox and furnace .
During this period also, 30% - 40% of total air flow is maintained to have an air rich furnace and to avoid possible unhealthy furnace condition. Again all the aux. & end air dampers are opened to distribute the excessively admitted air away from the operating burners and to pass only the necessary air behind the operating burners at appropriate velocity , for successful burner light up & stable flame .
Around 40 mm wc WB to Furnace dp is the pressure estimated as required to admit 30% - 40% of air flow with all the aux. & end air dampers modulating with reasonable opening.
Whenever one or more oil burners are put into service the associated elevation of aux. air dampers modulate

as a function of oil header pressure, to provide required combustion air. The other aux. air dampers continue to maintain 40mmwc WB to Furnace dip.

At boiler less than 30% MCR, each elevation of oil burners shall not be loaded more than 10% -12% MCR (high capacity provided), since no adequate combustion air will be available behind oil burners, under this operating conditions. If found necessary total air flow may be marginally increased for better flame condition.

BOILER LOAD above 30%

When the unit load exceeds 30% MCR, each differential set point is changed and ramps to a higher setting (approx. 100 mm WC). Simultaneously, the aux. air dampers associated with the coal elevations not in service close in timed sequence starting with the upper elevations of dampers and progressing to the lowest elevation. The above 100 mm wc is the predicted value required to admit the total SA at design air velocities with all dampers opened to reasonable %.

When the unit load is reduced below 30% loading, the aux. air dampers open in a timed sequence starting with the lowest elevation of dampers. Simultaneously the diff. set point changes to a lower setting.

The aux. air dampers associated with the oil elevations modulate as a function of oil header pressure when oil is being fired and opens more and more with increased firing rate. Otherwise they open and close with the balance of aux. air dampers.

The bottom end air damper is normally kept open to a fixed pre-determined position, to reduce unburnt coal dust fall out.

All the aux. air dampers maintain the status quo upon a boiler trip and will open fully when both FD fans are OFF.

SECONDARY AIR DAMPER CONTROL SYSTEM

Intruduction :

SADC system is used in a corner fired, natural circulation, and balanced draft unit.

It controls 6 nos. Fuel (coal) air dampers in A, B, C, D, E & F ELEVATIONS, 3 nos. Fuel (oil) air dampers in AB , CD & EF elevations , 6 nos. of auxiliary air dampers in AB , BC , CD , DE , EF & FF elevations and 2 nos. of OVER FIRE air dampers . There is a provision for firing light oil in elev. AB alone

OPERATION ::

1) AUXILIARY AIR DAMPERS :- During the furnace purge period & initial operation of the unit up to 30% loading , all elevations of aux. air dampers (AB,CD,DE,EF & FF) modulate to maintain a pre-determined (approx. 40 mm wc) set point dp. between furnace and windbox . As the unit loading increases above 30% the setpoint also ramps up automatically and at pre-determined breakpoint the slope of the ramp changes . Finally at 60% boiler load the setpoint settles at 100 mm wc.

After 30% boiler load, the aux. air elevation associated with the main fuel elevation in service modulates to maintain the varying dp. Those not associated with any elevation in service are closed from top to bottom. The closing signal comes from FSSS .

2) FUEL AIR DAMPERS (COAL) :- When an elev. of main fuel is started, the associated coal air dampers open & modulate as a function of feeder rate signal when coal is fired. A coal air damper is selected to be closed when the respective pulverisers are OFF.

Their operation is independent of boiler load. All fuel air dampers are normally closed. They open 50 secs. after the associated feeder is started and a particular speed is reached; then it modulates as a function of feeder speed. 50 secs. after the feeder is removed from service, the associated fuel air dampers close. They will open fully when both FD fans are OFF.

3) FUEL AIR DAMPERS (OIL) *:-* The aux. air dampers at elev.- AB,CD & EF act as fuel air dampers when oil firing is taking place and is open to a preset position . These aux. air dampers are to be closed if there is a back up trip in respective elevation & adjacent pulverisers are off & there is a " NO BOILER TRIP " signal present .

4) OVER FIRE AIR DAMPERS: - These dampers are positioned as a function of the boiler load. The lower OFA dampers start opening at 50% boiler load & are fully open when the boiler load reaches 75% .The upper OFA dampers start opening at 75% boiler load & are fully open when the boiler load reaches 100% load.

Importance of SADC settings :- Successfully establishing or lighting up of an oil burner and its stability .-- keeping open of aux. air dampers for initial purging and for air rich furnace volume at lower loads .-- best

ignition stability , distance of ignition point from coal nozzles , furnace stability , reliable and constant flame scanner pick-up .

HEA Igniter

High Energy Arc Igniter is designed to ignite a variety of fuel ranging from high speed diesel to HFO. The equipment gives a high intensity electric spark which readily ignites the oil particles surrounding the spark, thus creating a flame pocket in the oil spray. The flame propagates into the oil spray from this pocket giving a successful ignition. Each discrete spark provides a large burst of ignition energy as the current reaches a peak value of around 2000 amps. These sparks are effective in lighting up a well ataomised oil spray & also capable of blasting off any coal particle or oil muck on the surface of the spark rod.

HEA-Ignitor works in combination with the Discriminating Flame Scanner which is capable of sensing the associated oil flame only. The discriminating flame scanner senses the flame immediately after the ignition permits the firing to continue.

Major components =

1) Ignition Exciter: stores up electrical energy & releases energy at a high voltage over a short duration.
2) Spark rod retractor :: pneumatically operated retract mechanism which advances the spark tip into oil spray & retracts back after ignition .
3) Flezxible cable
4) Flexible spark rod
5) Spark tip
6) Guide pipe

AIR COOLED GUN

The atomiser assembly of an operating gun is protected from the hot furnace radiation by the flowing fuel oil & steam which keeps it relatively cool . Once the burner is stopped , there is no further flow of oil or steam. Under such situation it is required to withdraw the oil gun from firing position in order to protect the atomisers from damages due to overheating.

In this project the oil guns are provided with air cooling provision. The cap that nut that holds the atomiser to the oil gun body is provided with specially sized cooling fins. A sleeve over the cap nut protects the fins and also directs the cooling air effectively over the atomiser spray plate. The oil gun guide pipe assembly & the vaned diffuser have been appropriately dimensioned to accommodate the finned cap nut & for best cooling efficiency. The low pressure air tapped at FD fan cold air interconnecting duct is piped to the individual oil gun guide pipe with flexible hoses at the required. Places. Thus oil gins can always be left in firing position and with cooling air the atomiser parts are kept clean, free from any dripping oil or coal.

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22

PRE-START CHECKS AND START UP PROCEDURE OF BOILER & ITS AUXILIARIES

BOILER:

Introduction: The Steam Generator of BkTPP is of BHEL make and radiant, reheat, dry bottom, natural circulation, single drum , semi outdoor , direct corner fired, balance draft , top supported type. And there is provision of firing of coal as principal fuel.

The ancillary equipment comprises of pulverized coal and oil firing equipment and soot blower system. The firing equipment consists of Coal Mills, Oil & Coal Burners and mechanical draft system.

BOILER :

The Unit comprising of Furnace, Super heaters, Reheater, LTSH and Economiser along with Drum and Downcomers are suspended from steel works and is free to expand in downward direction. The Boiler heating surfaces are contained in three main compartments namely- the furnace, vestibule and cage enclosure. The Super Heater steam system has mainly three sections, the low temperature super heater (LTSH), the radiant platen super heater and final super heater. Two nos. desuperheaters have been provided in between the LTSH & platen super heater as well as in between platen SH & final SH for controlling the

super heater steam temperature over a wide load range. The complete second pass of the Boiler up to economizer has been covered with steam cooled super heater wall section. The complete reheater is in one section which has been located in the horizontal pass of the boiler (just above the notch) , in between the platen and final superheater section. An emergency desuperheating unit has also been provided at the inlet of the reheater.
Two Steam Coil Air Pre Heater (SCAPH) are provided to preheat the air discharged by the F.D. fans during initial start up. The SCAPHs are to be charged to maintain cold end temperature of Air Pre heater to prevent cold end corrosion. The boiler has two nos. recuperative tubular air pre heaters.
The draft system includes two Induced Draft Fans and two Forced Draft Fans and Scanner Air Fans. The draft system provides the air required for combustion of fuel and also expels the flue gases maintaining balance draft. Electrostatic Precipitator is provided in each flue gas path for collecting dust particles in flue gases.
The boiler has direct pulverized coal firing system which comprises of Raw Coal Bunkers, R.C. Feeders, Ball & Race Mills, Discharge Piping, and Coal Nozzles with tilting tangential firing system, Primary Air Fans, Seal Air Fans etc. Each Mill supplies the pulverized coal to all burner assembly for all four corners of an elevation. Thus there are six tiers of coal burners. The entire burner assembly for all four corners can be tilted in vertical plane (+300 to - 300) by a burner tilting arrangement; basically for controlling the steam temperature and particularly the hot reheat steam temperature. To ensure increased safety, reliability and caring operation, the fuel firing system is equipped with **Furnace Safeguard Supervisory System** (FSSS).

BOILER TECHNICAL SPECIFICATION:

i. FURNACE : Width – 13.868 M , Depth- 10.598 M, Volume-52.02 M3
ii. SUPERHEATER : Total heating surface- 6600 M^2 LTSH – 3700 M^2
Platen –19015 M2 (Projected)
Final SH-1543 M2
iii. REHEATER : Type- Pendant , Total heating surface – 2820 M2.
iv. ECONOMISER : Plain Tube, Total heating surface- 7762 M2, No. of block- 2.
v. Air Heater : Type- Recuperative tubular. Total heating surface- 19840 M2 per Air Heater.

BOILER MAIN PARAMETERS:

	Unit	**BMCR**	**NCR**	**75% MCR**	**60% MCR**	**HP Htr. out**
Generation	MW		210	157.5	126	210
Main Steam Flow	T / Hr.	680	623.8	458.2	371.6	559.3
Reheat Steam Flow	T / Hr.	570	559.4	415.1	338.7	554.1
Boiler Heat Duty	M Kcal / Hr.	448.4	412.6	315.1	260.5	429.5
Press. at SH outlet	Kg/cm2	155.00	154.1	151.8	150.9	153.1
Temp. at SH outlet	^0C	540	540	540	540	540
Press. at Reheater inlet	Kg/cm2	37.9	37.2	27.4	22.2	37.3
Temp. at Reheater inlet	^0C	344	342	318	313	340
Press. at Reheater outlet	Kg/cm2	36.1	35.4	26.1	21.2	35.6
Temp. at Reheater outlet	^0C	540	540	540	540	540
Feed Water Temp.	^0C	245	245	230	221	163
Ambient Air Temp.	^0C	27	27	27	27	27
Combustion Air Temp. (Secondary)	^0C	279	273	262	262	293
Fuel Quantity	T / Hr.	121.7	111.8	86.1	70.4	116.7
Air Quantity (Total)	T / Hr.	838	769	586	527	799
Flue Gas Temp. at Boiler exit	^0C	141	135	132	130	130

Efficiency based on HHV	%	87.27	87.50	87.55	87.36	87.86

***** CONDENSER INITIAL FILLING (using CTP)**

***** DEARATOR INITIAL FILLING (using CTP) :**

****** BOILER FILLING FOR BOILER LIGHT- UP (USING CTP):**

PRE CHECK-UP:

- Work permit on various boiler areas such as Furnace, APH, ID fans, ESP Ducts, Dampers
    - etc., cancelled and men, material removed from these areas.
- Open Local/ remote instruments isolating valves.
- Check all the soot-blowers are in retracted condition.
- Check the Instrument and Service air pressure is sufficient for boiler area.
- Sufficient DM water is available in Condensate Storage tank (up to 8mtrs. Level).
- Check the Bottom Ash equipment available for taking it in service.
- Boiler manholes, peepholes are in closed condition.
- Open the Boiler Drum vent (B20, B21, B22 & B23) valves.
- Master drain valve (B 99, SD20 → to IBD tank) must be closed.
- Boiler drain header inlet valves from ring header drain (B 104,105,106,107 & B 94, 95, 96, 97)
    - must be opened.
- Open the Economiser & boiler filling line v/v (E21 & E22).
- Close the Hydro-test connection Valve (E14).
- Ensure the Intermittent Boiler blow-down valve SD21 & B93 are operative by opening/ closing the valve from CRT and checking the feedback in DAS/ CRT and kept the v/v in closed condition.
- Ensure the Feed control station to Economiser v/v E2 is operative by opening/ closing the valve from CWD03/CRT and checking the feedback in CWD03 / CRT and kept the v/v in closed condition.
- Ensure the Feed control station to Economiser v/v E18 is operative by opening/ closing the valve from CRT/ CWD03 and check the feedback in CWD03 / CRT and kept the v/v in opened condition.
- Open the Economiser vent valves (E12 & E13).
- Ensure the Emergency drum drain valve B91 & B92 are operative by opening/ closing the valve from CRT/ CWD03 and check the feedback in CWD03/ CRT and kept the v/v in closed condition.
- Ensure the Emergency drum drain valve analog is zero.
- Ensure the Continuous blowdown (CBD) valve B83 & B84 (HAD12AA301) are operative by opening/ closing the valve from CRT and check the feedback in DAS/ CRT and kept the v/v in closed condition.
- Please also keep the manual isolating v/v (SD18 & B85) of CBD B83 and the manual isolating v/v (SD19 & B86) of CBD B84 in closed condition.
- Open the SH vent valves (S9 -14, S19, 20, 25, 26, 28, 29).
- Close the SH filling line v/v (S59).
- Open the SH Drain header drain v/v (S60) to IBD Tank.
- Open the inlet v/v to SH drain header (S51-58).
- Close the start-up vent v/v (SD49, 50).
- Close the steam line v/v for soot-blowing (S117) & the motorised v/v S118
- Open the HRH & CRH vent valves (R1-4) and drain v/vs.
- Ensure the Stage I DESH attemperation isolating valves are closed.
- Ensure the Stage II DESH attemperation isolating valves are closed.
- Ensure the RH attemperation isolating valves are closed.
- Check drum level indicators are in zero (-512 mm of wcl) position both at CWD03 and CRT.
- Put the local gauge glass in service.
- Check the Hydrastep level indicator- All RED.

CTP LINE-UP:

- Check the initial Condensate storage tank level (CST-1/ CST-2) in CRT/ DAS.

- Check the LP Chemical system is lined up at CTP discharge. Open the CHD-13 & CHD-09 for Hydrazine dosing and open the CHD-13& CHD-09 for Ammonia dosing.
- Check the 415V voltage is available for CTPA & CTPB.
- Check 415 V voltage is available for Discharge valves DM36 , DM39 & DM46 and the lockout switch in released condition and selected for remote operation.
- Check the Discharge valves DM36, DM39 & DM46 are operative from CRT and kept in closed condition.
- Keep the manual isolation v/v of CTP Discharge header DM 38 close and DM 35 open.
- Keep the manual isolation v/v of CTP Discharge DM 10 and DM 13 open.
- Check the Breakers are in Service & Switchgear 'Not disturbed'.
- Check "DRUM LVL V. Low" & "DRUM LVL Low" alarms are already appearing in CWD03 and in CRT.
- Check "DRUM LVL High" & "DRUM LVL V. High" alarms are not appearing in CWD03 and in CRT.
- Open the CTP suction valves DM-6 or DM-7 from local control panel after releasing the lockout switch, which was selected for remote operation.
- Check the manual suction isolation v/v (DM-8, 15, 11, 17) are fully opened.
- Start CTPA (LCR21AP001) or CTPB from local control panel.
- Check the ON Feedback locally and in the DAS / CRT monitors (Change of colour in the monitor diagram).
- Open the CTP discharge valve DM36 from CRT.
- Check the open feedback in CRT.
- Check the Drum level in DAS/ CRT & in Recorder is increasing and also in local gauge glass.
- Check "Drum LVL V Low" & "Drum LVL Low" alarms are disappearing one after another in CWD03 and in CRT.
- Check locally the CTP suction strainer DP is varying and within the limit.
- Check the CTP discharge pressure locally (18Kg/cm2).
- Run the CTP till the drum level Gauge glass displays three ports.
- Check the Hydrastep level indicator- 03 (three) ports (-75mm).
- Check the Drum level in DAS/ CRT & in Recorder.
- Stop CTP A/B and check OFF feedback locally and in DAS/ CRT.
- Close the suction valve DM-6 or DM-7 from local control panel.
- Close the discharge valve DM36 .
- Close the Economiser & boiler filling line v/v (E21 & E22).
- Check the final Condensate storage tank level (CSTA/B) in CRT/ DAS.
- Check the difference of level (initial- final) of Condensate storage tank.
- Show the total amount of DM water transferred.

Ignition oil start up for HFO & LFO

LDO SYSTEM :.

HFO SYSTEM:

INDUCED DRAFT FANS :

ID Fan # A /B Start up:

i. Preparation for start-up

A. Line up of the ID Fan A Auxiliaries (Lube Oil Pump):

- Check the Oil tank level at local gauge glass for adequate.
- Check there is no alarm of "Oil tank level low" in DAS/ CRT (set at < 50%).
- Check for either of the two Lube oil cooler is in service (DM cooling water inlet and outlet isolating valves are open).
- Check, the alarm 'IDF-A DP across Lub oil Filter high > 0.6 ata.' is not appearing in DAS/ CRT and CWD01 alarm facia.

- Check whether, the 415V supply to Lub oil pumps are healthy.
- Check whether, all the MCC modules are in Service (A & B).
- Lockout switches for all the pump motors are normal (released condition) and have been selected for remote operation.
- Put the Lube oil pump A & B in ‘MAN’ mode.
- Check the ‘OFF’ feedback of Lube oil pump A & B in DAS / CRT and unit control panel (CWD).
- Ensure that the alarm ‘IDF-A Lub oil pressure low < 0.4 ata’ is not appearing in DAS/ CRT and CWD01 alarm facia.
- Start the Lube oil pump A either from CRT or from UCP (CWD).
- Check the discharge pressure locally.
- Check the pump ’ON’ Feedback in the CRT monitor and in CWD.
- Stop Lube oil pump A.
- Check the discharge pressure locally .
- Check Lube oil pump B should not start.
- Check the ‘OFF’ Feedback in the CRT monitor and in CWD.
- Start the Lube oil pump B either from CRT or from UCP (CWD).
- Check the discharge pressure locally .
- Check the pump ’ON’ Feedback in the CRT monitor and in CWD.
- Stop Lube oil pump B.
- Check the discharge pressure locally .
- Check Lube oil pump A should not start.
- Check the ‘OFF’ Feedback in the CRT monitor and in CWD.
- Keep the Lube oil pump A in MAN mode & Lube oil pump B in AUTO mode.
- Check the Lube oil pump B will start instantly due to low discharge pressure (< 0.6ata).
- Put the Lube oil pump A In AUTO mode.
- Check the Filter DP locally .
- Check the Lube oil pressure is OK and > 0.8 ata. (Normally pressure should be ≅ 1.8 kg/cm2 when one pump is running.)
- Check the ID Fan A Motor Winding temperatures & Bearing temperatures are in Ambient in DAS/ CRT display.
- Check the ID Fan A Fan Bearing temperatures are in Ambient in DAS/ CRT display.
- Check the ID Fan A Fan Bearing vibrations are showing zero value in DAS/ CRT display.

B. Line up of the ID Fan A:

- Open the DMCW isolating Outlet & Inlet valves to the ID fan A sleeve bearings.
- Open the DMCW isolating Outlet & Inlet valves to the ID fan A Hyd. coupling Coolers A & B.
- Ensure that the alarm ‘IDF-A Hyd coupling trouble’ is not appearing in DAS/ CRT and CWD01 alarm facia
- Ensure that the alarm ‘IDF-A brg/ wdg temp/vib high’ is not appearing in DAS/ CRT and CWD01 alarm facia.
- Ensure that the alarm ‘IDF-A DP across lub oil filter high > 0.6 ’ is not appearing in DAS/ CRT and CWD01 alarm facia.
- Check ESP A Inlet gates are open.
- Check ESP A Outlet gates are open.
- Check ESP B Inlet gates are open.
- Check ESP B Outlet gates are open.
- Check the operation of the Hydraulic scoop either from CWD or from CRT and ensure scoop position minimum.
- Check ID Fan A Control damper is closed.
- Check ID Fan A Inlet / Outlet gates are closed.
- Check any one FD Fan discharge damper is open.
- Check the 6.6 KV voltage is available.
- Check the Breaker is healthy and DC control supply is ‘ON’.
- Check the lockout switch is normal.
- Check the Fan is selected for remote operation.

- Check the OFF feedback of ID Fan A in DAS/ CRT & UCP.
- Check , no electrical tripping is present for ID Fan A

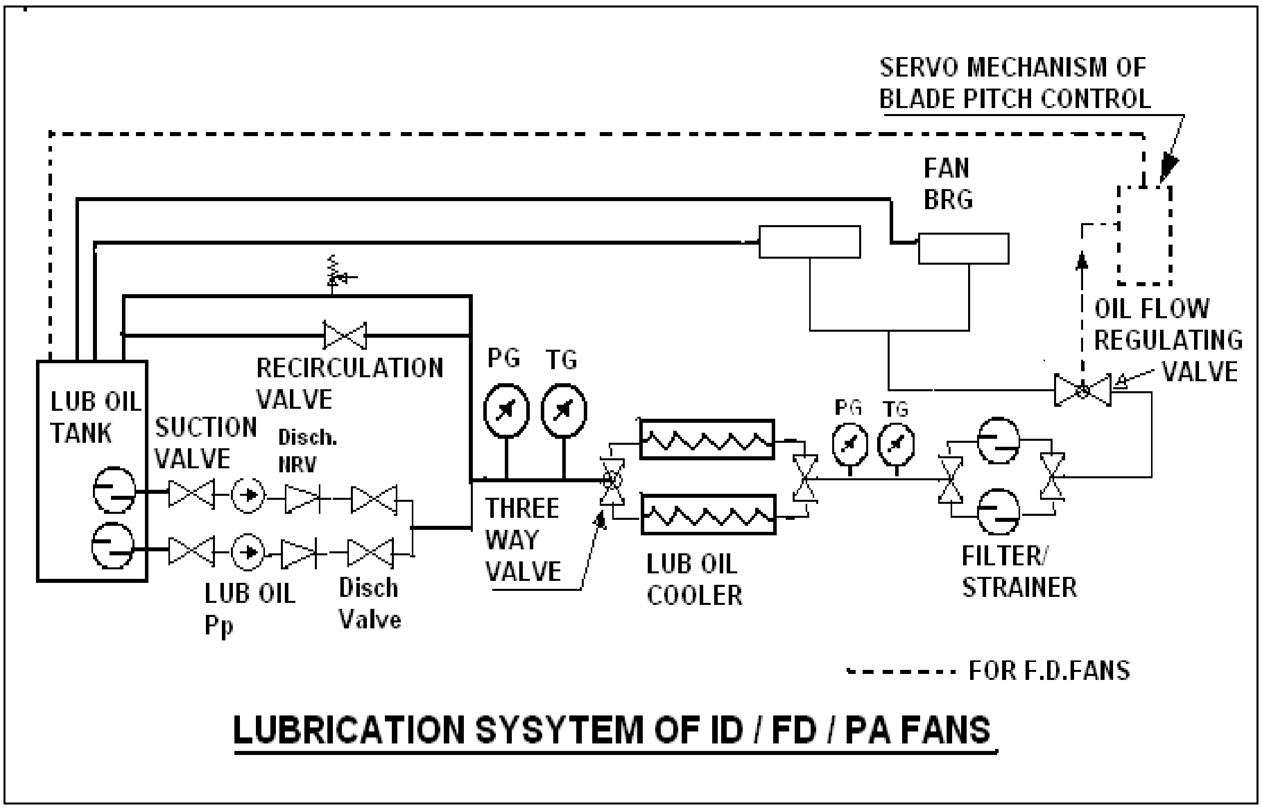
Initiate ID Fan A start command and verify:

ID FAN A:-

- Select the ID FAN A sequence control in 'MAN' mode from CRT/CWD.
- Issue the start command for ID Fan A O/L Gate Blower Motor either from CWD or from CRT.
- Check the 'ON' feedback in DAS/ CRT & CWD.
- Keep open the ID Fan B Inlet / Outlet gates .
- Increase the ID Fan A scoop .
- Issue the start command for ID Fan A either from CWD or from CRT.
- Check the ID Fan A will not start.
- Decrease the ID Fan A scoop to minimum value.
- Start ID Fan A either from CWD or from CRT.
- Check the 'ON' feedback in DAS/ CRT & UCP.
- Check the Ampere pegs up & drops down to no load Amps in DAS/ CRT monitor & in the Unit Control Desk Ammeter.
- Check the 6.6 KV Bus voltage dips slightly.
- Open the ID Fan A Inlet / Outlet gates
- The ID Fan B Inlet / Outlet gates starts closing automatically.
- ID Fan A Inlet flue gas pressure slightly reduces .
- ID Fan A Outlet flue gas pressure slightly increases .
- Check the ID Fan A Motor Winding temperatures & Bearing temperatures are changing in DAS/ CRT display.
- Check the ID Fan A Fan Bearing temperatures are changing in DAS/ CRT display (<70 degree).
- Check the ID Fan A Fan Bearing vibrations are changing in DAS/ CRT display.
- Raise the ID Fan A scoop position by 05% from CWD/ CRT.
- Check the position feedback (5%) in CWD/ CRT.
- Raise the ID Fan A Control damper position by 05% from CWD/ CRT.
- Check the Control damper position feedback in DAS/ CRT & UCP.
- Check the ampere increases in DAS/ CRT & UCP.
- ID Fan A Inlet flue gas pressure reduces (HNC10CP101) further.
- Furnace pressure drops to -'ve side.

INTERLOCK AND PROTECTION (ID FAN):

- 'ID Fan lube oil Δp high' alarm appears at >0.6 ata
- 'ID Fan lube oil pressure low ' alarm appears and standby lube oil pump starts at < 0.6 ata
- 'ID Fan lube oil pr. V. low" alarm appears and Fan trips at <0.4 ata.
    - 'IDF Lub. oil tank level low' < 50% alarm at DAS & CRT.
- 'ID Fan HYD. Coupling W.O temp. high' appears at >100 ^{0}C
- 'ID Fan HYD. Coupling. W.O. temp. very high' appears at >110^{0}C, ID Fan trip.
- 'ID Fan W/O temp. at cooler outlet hi' appears at >80^{0}C.
- 'ID Fan W/O temp. at cooler outlet very hi' appears at >90^{0}C, ID Fan trip.
- 'ID Fan Δp across HC L.O. Filter hi' appears at >0.4 kg/cm2
- 'ID Fan HC lub oil pr. Low' appears at <0.8 Bar.
    - 'ID Fan HC lub oil pr. Very appears at <0.6 Bar., -ID Fan trip.
- 'ID Fan bearing vibration ' high'/v.High(ID Fan trip) ---4.5/9.0mm/sec
- 'ID Fan motor DE/NDE bearing temp. high/ v.high (ID Fan trip)--- 85^0/90^{0}C
- 'ID Fan DE/NDE bearing temp.' high'/v.High(ID Fan trip) ---77^0/82^{0}C
- 'ID Fan motor winding temp. ' high'/v.High(ID Fan trip) ---125^0/130^{0}C



FORCED DRAFT FAN

FD FAN # A / B START UP :

i. Preparation for start-up

Line up of the FD Fan A Auxiliaries (Lube Oil Pump):

- Check the Oil tank level at local gauge glass is adequate.
- Check there is no alarm of "Oil tank level low . in DAS/ CRT (set at < 50%).
- Check for either of the two Lube oil cooler is in service (DM cooling water inlet and outlet isolating valves are open).
- Check, the alarm 'FDF-A DP across Lub oil Filter high > 0.6 ata. .' is not appearing in DAS/ CRT and CWD01 alarm facia.
- Check whether, the 415V supply to Lub oil pumps are healthy.
- Check whether, all the MCC modules are in Service (A & B).
- Lockout switches for all the pump motors are normal (released condition) and have been selected for remote operation.
- Put the Lube oil pump A & B in 'MAN' mode.
- Check the OFF feedbacks of Lube oil pump A & B in DAS/ CRT & unit control panel (CWD).
- Ensure that the alarm 'FDF-A Lub oil pressure low < 0.4 ata' is not appearing in DAS/ CRT and CWD01 alarm facia.
- Start the Lube oil pump A . either from CRT or from UCP (CWD).
- Check the discharge pressure locally .
- Check the ON Feedback in the CRT monitor and in CWD.
- Stop Lube oil pump A either from CRT or from UCP (CWD).
- Check the discharge pressure locally .
- Check Lube oil pump B should not start.
- Check the OFF Feedback in the CRT monitor and in CWD.
- Start the Lube oil pump B (HLB11AP002) either from CRT or from UCP (CWD).
- Check the discharge pressure locally .

- Check the pump 'ON' Feedback in the CRT monitor and in CWD.
- Stop Lube oil pump B either from CRT or from UCP (CWD).
- Check the discharge pressure locally .
- Check Lube oil pump A should not start.
- Check the OFF Feedback in the CRT monitor and in CWD.
- Put the Lube oil pump A in MAN mode & Lube oil pump B in AUTO mode.
- Check the Lube oil pump B will start instantly due to low discharge pressure (<0.6ata).
- Put the Lube oil pump A In AUTO mode.
- Check the Filter DP locally.
- Check the Lube oil pressure is OK and > 0.8 ata. (Normally pressure should be ≅ 1.8 Kg/ cm2 when one pump is running.)
- Check the FD Fan A Motor Winding temperatures & Bearing temperatures are in Ambient in DAS/ CRT display.
- Check the FD Fan A Fan Bearing temperatures are in Ambient in DAS/ CRT display.
- Check the FD Fan A Fan Bearing vibrations are showing zero value in DAS/ CRT display.

ii. Line up of the FD Fan A: -

i. Open the DMCW isolating Outlet & Inlet valves to the FD fan A Lub oil coolers.
ii. Ensure that the alarm 'FDF-A DP across lub oil filter high > 0.6 ' is not appearing in DAS/ CRT and CWD01 alarm facia.
iii. Ensure that the alarm 'FDF-A ctrl oil pr. Low <6 ata ' is not appearing in DAS/ CRT and CWD01 alarm facia.Check FD Fan A control oil pressure is adequate (>8 ata).
v. Ensure that the alarm 'FDF-A brg / wdg temp / vib high' is not appearing in DAS/ CRT and CWD01 alarm facia.
vi. Check Fan blade pitch is operating from remote and at minimum position.
vii. Check Outlet gate is in closed condition.
viii. All manual valves of Combustion Chamber wind box are in open condition.
ix. Check ID Fan A or B is in running condition.
x. Check the 6.6 KV voltage is available.
xi. Check the Breaker is healthy and DC control supply is 'ON'.
xii. Check the lockout switch is normal.
xiii. Check the Fan is selected for remote operation.
xiv. Check the OFF feedback of FD Fan A in DAS/ CRT & UCP.
xv. Check, no electrical tripping is present for FD Fan A.

iii. Initiate FDFan A / B start command and verify

FD FAN A:-

- Select the FD FAN A sequence control in 'MAN' mode from CRT/CWD.
- Keep open the FD Fan B Outlet damper .
- Increase the Fan blade pitch .
- Put Start command for FD Fan A either from CWD or from CRT.
- Check the FD Fan A will not start.
- Decrease the Fan blade pitch/ impeller . to minimum.
- Start FD Fan A either from CWD or from CRT.
- Check the ON feedback in DAS/ CRT & UCP.
- Check the Ampere pegs up & drops down to no load Amps in DAS/ CRT monitor & in the Unit Control Desk Ammeter.
- Check the 6.6 KV Bus voltage dips slightly.
- Open the FD Fan A Outlet gate .
- Check the FD Fan B Outlet gate starts closing.
- Check FD Fan A discharge pressure .

- Check the FD Fan A Motor Winding temperatures & Bearing temperatures are changing in DAS/ CRT display.
- Check the FD Fan A Fan Bearing temperatures are changing in DAS/ CRT display.
- Check the FD Fan Bearing vibrations values go up in DAS/ CRT display.
- Check SCAPH inlet damper & outlet damper are opened from CWD/CRT. Check the feedback at CRT/CWD.
- Check SCAPH bypass damper is in closed condition.
- Raise the FD Fan A blade pitch by 10%.
- Check the pitch position feedback in DAS/ CRT & UCP.
- Check the ampere increases in DAS/ CRT & UCP.
- FD Fan A discharge pressure increases further.
- Secondary airflow to Wind box LHS/ RHS increases.
- Blade pitch controller minimum permissive goes off.

SCAPH CHARGING

- Steam Coiled Air Preheater is charged initially to increase the Flue gas temperature to avoid cold end corrosion.
- Check whether, SAD8A & SAD9A is in open condition and SAD3A is in closed condition.
- Check the PRDS systems charged and put on 'AUTO'.
- Check whether the Boiler PRDS pressures set at 3 Kg/ cm^2 and temp. at > 200^{o}C.
- Open AS-66 & ASS-01 valves locally.

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SEQUENTIAL LIGHT UP PROCEDURE & LOADING OF BOILER FROM VARIOUS START UP CONDITION UPTO FULL LOAD

1. BOILER PURGE:

<u>Check before Purge:</u>

1. Any ID/FD Fan (set) combination on.
2. Boiler Trough Seal is charged.
3. All the vents and drains are in open condition.
4. Any one BFP (A/B/C) is running.
5. Bi-colour gauge glass & Hydrastep are in service.
6. MS Stop valve is in closed condition.
   i. Increase total air flow set point > 30% but <40%
   ii. Verify Purge Permissive conditions

<u>Check the conditions in CWD as well as in CRT.</u>

- ✓ No boiler (MFR A, B&C) trip signal.
- ✓ AB elevation Light oil nozzle valves are closed.
- ✓ Oil trip valves (LOTV) are closed.
- ✓ Oil trip valves (HOTV) are closed.
- ✓ All scan no flame {Discriminating (AB, BC, CD) & Fire Ball (AB, BC, CD, DE & EF)}.
- ✓ All Feeders (A-F) are not running/OFF.
- ✓ All elev. (AB, CD & EF) Heavy oil nozzle valves are closed.
- ✓ All PA Fans (A-F) off.
- ✓ All hot air gates (A-F) closed.
- ✓ All aux. air dampers (SADC) modulating.
- ✓ Air flow proven (> 30% & < 40%).

✓ All FSSS Power supply available.

iii. Verify "PURGE READY" lamp on.
iv. Start purge by pressing "PUSH TO PURGE" push button in FSSS plaque or in CRT and verify:

- "PURGING" lamp flickering for 5 Min.
- "PURGE COMPLETE" lamp on
- MFT A, B & C reset (RED lamp goes 'OFF').
- "PUSH TO PURGE" lamp goes 'OFF'.
- "PURGE COMPLETE" lamp comes 'ON'.
- All causes of TRIP RED lamp goes 'OFF'.
- Boiler "Trip/ Normal" logs "Normal".

2. PREPARATION FOR BOILER LIGHT UP:

Ignition :-Light up

A. Preparation for Ignition :-

START PERMISSIVE:

I. 220V DC Power is available.
II. Unit critical (24V) DC Power is available.
III. 110V AC Power is available.
IV. Verify ESP is in service.
V. Check and put all the instruments in service after opening all the isolating v/vs.
VI. Verify Scanner Fan is running (ON feedback is available)

Scanner Air Fan (AC/ DC):

- Check and put all the instruments in service.
- Ensure the readiness of Electrical System (check the 415v AC and 220 V DC power supply is available, MCC is in service & no thermal over load tripping for both the Fans is present). Check the 'Off' feedback is available at local control panel as well as at CRT/CWD for Fans A, B.
- Check, there is no Trip indication for both the Fan at CRT and CWD.
- Check the Lock out switches is normal (released condition).
- Select the both the Fans for remote operation.
- Check and open the Fans suction dampers SID2A (HHS10AA201) and SID2B (HHS20AA201) and verify the emergency suction damper SLD1 (HHS10AA101) is in closed condition.
- Start the Fan A (HHS10AE001) either from CWD or from CRT.
- Check the 'On' feedback is available at CRT /CWD 01.
- Verify the amps at CRT/DAS.
- Verify scanner air fan discharge press (HHS10CP102) at CWD indicator as well as at DAS/CRT (approx. 550mmwcl.).
- Verify no 'DP across scanner fan suction filter (HHS10CP201) low < 4mmwcl' alarm is present at CRT/CWD.
- Verify no 'DP across scanner fan suction filter (HHS10CP202) high >15mmwcl' alarm is present at CRT/CWD.
- Verify the scanner fan suction filter DP (HHS10CP101) reading at DAS/CRT.
- Verify the scanner fan discharge to furnace DP (HHS10CP103) reading at DAS/CRT.
- Verify the interlocks: In case of running scanner air fan trips auto starting of DC fan or vice-versa.

- Verify the interlocks: In case of running both FD fan trip auto opening of emergency suction damper SLD1.
- Verify the interlocks: In case of failure of unit critical power auto opening of emergency suction damper SLD1.
- Verify the interlocks: In case of scanner fan discharge to furnace DP low < 150mmwcl standby fan will start.

VII. Verify ECO re-circulation v/v (E-18) open.
VIII. Verify total air flow > 30% & <40% of rated
IX. Verify HP chemical dosing is in progress.
X. Verify HP-LP BP is in closed condition.
XI. Verify drum level is normal (-75mm).
XII. Keep Nozzle tilt in horizontal position after checking all the burner tilts from corners change accordingly by giving command either from CWD03 or from CRT monitor.
XIII. Verify the drain v/vs (CRH/ HRH etc.) are open.
XIV. Verify MS drain v/vs (Before MSV MS101, 102) are open.
XV. Verify the drum vent is open.
XVI. Verify all MS stop v/vs (Boiler area- MS 1-6) are closed from CWD/CRT.
XVII. Verify the atomising steam v/v open. (Pr. – 6.0 kg/cm2).
(Atomising steam is required to be charged if HFO is selected)

- Open all the Instrument line root valves and put the instruments in service.
    - Keep open all the drain and vent v/vs.
    - Open the inlet isolating manual v/v DS31A1.
    - Check the pressure at operating floor is 11 kg/cm2 (HJM10CP501).
    - Open the by-pass v/vs (DS32A1 & DS35A1).
    - Check the pressure (HJM10CP201) at CWD01 as well as at CRT/DAS.
    - Keeps open the drains & vents as long as water/ air come out.
    - Close the drains & vents.
    - Put the controller ASPRV (OS33A1) in auto mode (Set Pr. →6.0 kg/cm2) after opening the manual isolating v/v DS34A1 & A2.
    - Close the by-pass v/vs (DS32A1 & DS35A1) gradually and check the controller is operating following the set pressure.

XVIII. Verify the atomising air v/v open. (Pr. → 6.0 kg/cm2).
(Atomising Air is required to be charged if LFO is selected)
- Check the Boiler side Service Air pressure is adequate.
- Open all the Instrument line root valves and put the instruments in service.
- Open the inlet v/v (AO1A1) at the operating floor.
- Check the pressure is within 5.5 to 6.0 kg/cm2 (HJN10 CP501).
- Open all the manual isolating v/vs for AB elevation burners.

XVIII. Verify aux. air dampers are in service and full open.
- Verify the Oil and Aux air dampers (AB, BC, CD, DE, EF & FF) are full open for all the four corners at CRT/CWD01.
- Verify the Coal air dampers (A, B, C, D, E & F) are full open for all the four corners at CRT/CWD01.
- Verify the Over fire air dampers (OFA-U & OFA-L) are full open for all the four corners at CRT/CWD01.
- Check the WB to Furnace DP at CRT/ CWD01 and it is not > 240 mm Wcl.
- Set SADC system in Auto mode and verify the WB to Furnace DP set point is at 40 mm Wcl.
- Verify the Oil and Aux air dampers (AB, BC, CD, DE, EF & FF) are modulating for all the four corners to maintain the set DP.
- Verify the Coal air dampers (A, B, C, D, E & F) are full closed for all the four corners.
- Verify the Over fire air dampers (OFA-U & OFA-L) are full closed for all the four corners.
- Check the above feedbacks at CRT/ DAS and CWD01.

- Check the value of the WB to furnace DP at CRT/ DAS and CWD01.

XIX. Verify all the oil guns are engaged locally and engaged feedback is available in FSSS oil plaque/CRT.

XX. Verify all corners Local maintenance switch are placed in ‘REMOTE’ selection (at CRT & CWD01).

XXI. Verify all the manual isolating v/vs of atomising steam and oil are in full open condition. Check the same at CRT and CWD01.

XXII. Verify all the Scavenge v/vs are in closed condition. Check the same at CRT and CWD01.

XXIII. Verify the boiler ‘Purge’ has already completed and MFTs are in reset condition.

XXIV. Verify all corners nozzle valves (HO & LO) are in closed condition.

B <u>Heavy Fuel oil:</u>

1. Select oil H.O from CWD01 or from CRT.
   - Verify the Green lamp comes on both at CRT/CWD.
2. Open HFO re-circulation v/v (HORV) either from CWD or from CRT.
   - V/v open red lamp comes ON & close green lamp goes off
   - Verify the changes both at CRT/CWD.
3. Verify the Atomising steam controller (ASPRV) at operating floor is already in auto and maintaining the required pressure.
   - Verify there is no alarm at CRT/ CWD01 for atomising steam.
4. Open HOTV v/v either from CWD or from CRT.
   - V/v open red lamp comes ON & close green lamp goes off
   - Verify the changes both at CRT/CWD.

Note: As long as re-circulation v/v is full open and HO nozzle v/vs are closed, HOTV can be opened.

5. Close the short re-circulation v/v HO48A1 from CWD/CRT.
6. Issue open command of HFO (HOFCV) pressure controller from CWD/CRT.

   - Verify fuel oil flow (HJF 90 CF 101) starts increasing, as the re-circulation v/v is fully open the pressure also increases gradually.
   - Verify the HFO FLOW (HJF90CF101) rate at CWD recorder as well as at CRT.
   - Verify the HFO Flow is integrating at CWD HFO Integrator.

Note: Since the re-circulation v/v is full open the rate of pr. rise will be slow.

7. Adjust the set point of the controller to about 8 kg/cm2 and transfer the controller to auto ant observe:

   a. ‘AUTO’ lamp comes on, controller starts functioning.
   b. HFO temp. at boiler front starts increasing as hot fuel oil gets re-circulated throughout the boiler elevations.
   c. HFO hdr. Pr. low alarm clears on the oil pr. Increases more than 3 kg/m2.
   d. HFO hdr. Temp. low alarm clears at 95oC.

8. Push the push button PB1 “External” on the furnace probe LHS till it advances to 100%. Push stop push button.
9. Repeat the above (8) operation for RHS.
10. Press the “HO Select” in FSSS plaque (AB elevation)
    - Verify at CRT/ CWD that HO Select lamp ON; LO select lamp OFF.
11. Push “START” Push Button on pair 1-3 oil guns at AB elevation.
    Note: Corner No.1 is placed in service initially.

    - Aux. Air Dampers at the associated oil elevation are closed.

- Corner spark rod igniter advance red lamp comes and retract green lamp is 'OFF'.

Note : i) Spark occur for 15 secs.
ii) Atomizing steam v/v should open before the spark is in progress.

- HFO nozzle v/v will start opening and open F/B is available at CRT/ CWD.
- As the oil starts igniting the Disc. Flame scanner 1 scans flame.
- After 15 sacs. of the start command, the HEA igniters are retracted.
- When the 30 secs. (Thirty) counting period expires the "Start Corner No.: 3" signal will get established in the same manner as the oil gun at corner No.1.

Note: i) Pair 1/3 stop command doesn't hold good for 30 secs.
ii) If corner oil gun doesn't prove flame when 25 secs. counting expires, heavy fuel oil nozzle v/v will close, and a command to scavenge v/v will be then to scavenge the gun with atomizing steam.

12. Push the 2-4 oil gun pair "START" button at AB elevation. Same sequence described previously will occur first for corner 2 & then for corner 4.
    - Once corner 2 oil gun is proven ignition permit light comes 'ON' for Pulveriser A&B.
    - Corner 2 & 4 Disc. Scanner starts showing the flame and oil v/vs remain open.

C <u>Light oil:</u>

1) Select oil L.O from CWD01 or from CRT.
   - Verify the Green lamp comes on both at CRT/CWD.
2) Open LOTV v/v either from CWD or from CRT.
   - V/v open red lamp comes ON & close green lamp goes off
   - Verify the changes both at CRT/CWD.
3) Increase the output of LFO (LOFCV) pressure controller.
   - Fuel oil flow (HJF 30 CF 101) starts increasing, as the re-circulation v/v is fully open the pressure also increases gradually.
   - Verify the LFO FLOW (HJF30CF101) rate at CWD recorder as well as at CRT.
   - Verify the LFO Flow is integrating at CWD LFO Integrator.
4) Adjust the set point of the controller to about 8 Kg/cm2 and transfer the controller to auto.
   - 'Auto' lamp comes on, controller starts functioning.
   - LFO hdr. Pr. low alarm clears as the oil pr. Increases more than 3 Kg/m2.
5) Check the atomising air is available at the operating floor.
   - Verify there is no alarm at CRT/ CWD01 for atomising air.
6) Press the "LO Select" in FSSS plaque (AB elevation)
   - Verify at CRT/ CWD that LO Select lamp ON; HO select lamp OFF.
7) Push "START" Push Button on pair 1-3 oil guns at AB elevation.

   Note: Corner No.1 is placed in service initially.

   - Aux. Air Dampers at the associated oil elevation are closed.
   - Corner spark rod igniter advance red lamp comes and retract green lamp is 'OFF'.

   Note: i) Spark occurs for 15 secs.
   ii) Atomizing air v/v should prove open before the spark is in progress.

8) LFO nozzle v/v will start opening and open F/B is available at CRT/ CWD.
   - As the oil starts igniting the Disc. Flame scanner 1 starts showing flame.
   - After 25 secs. of the start command, if oil gun is proven the HEA igniter is retracted.
   - When the 30 secs. (Thirty) counting period expires the "Start Corner No. 3" signal will get established in the same manner as the oil gun at corner No.1.

Note: i) Pair 1/3 stop command doesn't hold good for 30 secs.
ii) If corner oil gun doesn't prove flame when 25 secs. counting expires, then Igniter to retract and heavy fuel oil nozzle v/v will close, and a command to scavenge v/v will be there to scavenge the gun with atomizing air.

9) Push the 2-4 oil gun pair "START" button at AB elevation. Same sequence described previously will occur first for corner 2 & then for corner 4.
- Once corner 2 oil gun proves ignition permit light comes ON for Pulv. A&B.
- Corner 2 & 4 disc. Scanner starts showing the flame as oil v/vs open.
- Furnace pr. increases as the oil guns are prove one after another.
- Check the AB damper position is in 'oil firing position'.

13. Adjust firing with 4 gun to get about 190-lit/min-fuel flow.

- Flue gas temp. at reheater inlet starts increasing slowly (RHS & LHS).
- Values shown by flue gas inlet pr. At platter SH, Horizontal & economizer etc. increase.
- After lapse of time furnace temp LHS / RHS starts increasing.
- Fuel oil flow increases as more no. of oil guns are in service.

Note: Air flow should be maintained > 30% to avoid air flow less than 30% trip.

- MS temp. before and after desuperheater starts increasing slowly.
- SH outlet temp. also starts increasing.
- Drum Metal temp. starts increasing.

Note: As the drum metal temp. approaches 100o C, the drum level will swell rapidly and require reduction of firing.

10) Increase ID Fan inlet vane controller to maintain furnace draft to -10 mm wcl.
11) Oil pressure decrease with each oil v/v proves and comes to steady at 8 Kg/m2 immediately.
- Furnace pr. increases as the oil guns are proven one after another.

3. Boiler warming :

a. Check before warm-up:

- All shut down clearances concerning boiler pressure parts, flue path and air lines are returned.
- Water level indicators, gauge glass, hydra step are in service.
- All local/ remote instruments are in service.
- All soot blowers and temperature probe are in retracted position.
- ESP is in service.
- The safety valves are in free position (i.e. not in gagged condition).
  - Boiler Drum Safety valves → SV1, SV2, SV3
  - Main Steam line Safety valves → SV4, SV5
  - Cold reheat line safety valves → SV6
  - Hot reheat line Safety valves → SV7, SV8, SV9
- All water side vent valves are open.
  - Boiler Drum vent valves → B20, B21, B22, B23
  - Economiser vent valves → E12, E13.
- All water side drain valves are closed.

- Boiler Drum drain valves from ring header drain → B104, B105, B106, B107 & B94, B95, B96, B97
- Master drain valves to IBD tank → B99, SD20.
- Intermittent blow down v/v (IBD) → SD21, B93

- Emergency drum drain v/v → B91, B92
- Continuous Blow down (CBD) → B83, B84
- All steam side drain valves are open.
  - Superheater drain header drain valves to IBD tank → S60
- All steam side vent valves are open.
  - SH, HRH & CRH .
- Primary SH spray and RH spray water line valves are closed.
- Adequate Fuel Oil (LDO/HFO) in Fuel oil storage Tank.
- Secondary Air Damper and Burner Tilt are free and at horizontal position.
- DMCW, SA and PA system are healthy.
- Lube oil system of ID Fan and FD Fan are running with normal pressures.
- Boiler Drum is filled-up up to light-up level (2 ports)
- Fuel Oil Pump is running on recirculation.
- Ensure BAS header pressure or Atomizing air pressure.
- Ensure the Start up vent valve SL6 (No. S49, S50) are in open.
- See that one ID Fan is running. (Check the procedure in ID Fan start up)
- See FD Fan is running. (Check the procedure in FD Fan start up)
- Put the aux. Air damper control on auto and check they are modulating as per control.
- Operate ID Fan scoops and FD Fan blade pitch to achieve >30% of total air flow at - 5 mm wcl Furnace pressure and 20 – 40 mm wcl Wind Box pressure.
- Start one Scanner Air Fan and put the other on auto.
- Check MFT is in reset condition.
- Ensure Boiler is in lighted up condition with AB 1,2 burners.
  - Press other corners/ elevation oil guns, if required.
  - Keep the RH drain valves and Vent valves open until vacuum pulling is started.
  - Start Boiler Feed Pump and keep it running on re-circulation and lined up to take water in Boiler Drum as and when necessary.
  - Boiler Pr. increase rate
    - The rate of rise of the boiler pressure is guided by the rate of rise of saturated steam temperature and normally it is limited to 550C per hour.
  - Verify valves position
    - >2 kg/cm2 drum press. : Close Drum vents & SH vents.
    - > 10 kg/cm2 drum press : Close SH drains and operate Start Up Vent to control rise of pressure.
    - Close RH vent and drain before raising vacuum in condenser
    - IBD will be operated to maintain the DRUM level swelling.
  - Initiate CD elevation start signal when boiler pressure reaches 15 kg/cm2.

For Start-up and line up of different equipment please go through the individual ATPs.

4. MAIN STEAM LINE WARM UP:

i. CHECK BEFORE CHARGING MS LINE:

- Wide open all drain line valves of MS line from CWD/ CRT or manually.
  - MS 107, MS 108 – manual-isolating v/vs
  - MS 105 (LBA12AA301), MS 106 (LBA22AA301) – motorised v/v.
  - Check the feedback at CWD/ CRT.
- Close MS Stop Valves (MAA10AA001 & MAA20AA001) at Turbine end from CRT/ CWD and Check the feedback at CWD/ CRT.

ii. CHARGING OF MS LINE:

- Check the main steam pressure (L & R) reaches at 30-35 Kg/cm2 at control desk indicator as well as at CRT.

- Open partially from CWD /CRT the MS Stop Valve MS1 Equalisers (MS-3&5 - LBA10AA311 & LBA10AA312) and MS2 Equalisers (MS-4&6 LBA20AA311 & LBA20AA312) of both L& R sides. Check the feedback at CWD/ CRT.
- Close the HP By-pass v/vs (BP1-MAN20AA401 & BP2-MAN30AA401) and their motorised by-pass warm up line isolation v/vs (BP3- MAN21AA301 & BP4- MAN31AA301) from CWD/ CRT. Check the feedback at CWD/ CRT.
- Observe no hammering of MS line.
- Observe the temperature (LBA20CT105 & LBA10CT105) and pressure (LBA10CP104 & LBA20CP104) of MS line are increasing gradually.
- Continue warming till MS line temperature and pressure matches with the Boiler steam parameters.
- Open MS Stop Valves (MS1- LBA10AA301 & MS2- LBA20AA301) from CRT/ CWD and check the feedback at CWD/ CRT. Also check that its equalisers are getting fully closed.

SELF AUX. STEAM FOR TAS SYSTEM

Before Charging Line up

- Boiler Drum pressure and temperature should be around 30 kg/cm2 and 350^{0}C.
- Open all Local / remote instruments isolating valves.
- Check the Instrument air pressure is sufficient for boiler area.
- Check the 415V is available for TAS system motorised v/vs.
- Open the Up stream manual isolating drain valves (AS113 & AS114) for High capacity PRDS and (AS122 & AS123) for low capacity PRDS line.
- Open the Up stream motorised drain valves (AS115 → LBA33 AA301) for High capacity PRDS & (AS124 → LBA43AA301) for low capacity PRDS line.
- Open the down stream drain valves through Steam Trap Stations (AS 131 to AS 150) of TAS line to Drain header to Flash pipe to IBD tank.
- Check the Controllers for Steam (AS22 & AS32) and water (CD65 & CD71) for de-superheating are operating on remote signal i.e. from CWD04 or from CRT and in closed condition.
- Check the isolating v/vs of the Controller for water spray (CD64 & CD70) for de-superheating and the by-pass v/v (CD68, CD74) are operating on remote signal i.e. from CWD04 or from CRT and in closed condition.
- Manual isolating v/vs (CD66 & CD72) of spray controllers are open locally.
- Check the motorised v/v of the interconnection of #2 & #3 are in closed condition & check the feedback at CRT/ CWD.
- Check the motorised v/v of the TAS station header (AS-39→ LBG1AA301) is in closed condition & check the feedback at CRT/ CWD.
- Check the motorised v/v for the High capacity PRDS line (AS-21) and bypass line (AS25) and the motorised v/v for the low capacity PRDS line (AS-31) and bypass line (AS35) is in closed condition & check the feedback at CRT/ CWD.
- Check manual isolating valve AS23 & AS33 are in open condition.
- Keep open the line drain v/vs after controller (AS116, 117 & AS 125, 126).
- Keep open the line drain v/vs after controller of the Desuperheater (CD114, 115).
- Check any one CEP is running and its pressure is showing at local pr. Gauge (LCA34CP301).

PROCESS:

- Open MS3, MS4, MS5, MS6 (Bypass of MS1 & MS2) for initial heating of MS line.
- After warm up of MS line open the MS1 & MS2.
- Partially open High Capacity PRDS Controller Bypass Valve AS 25 (LBA31AA101).
- Observe the temperature and pressure of TAS lines are increasing at CWD & at CRT.
- Line up De-superheating line.
  - Close the line drain v/vs after controller of the Desuperheater (CD115, 114).

- Open the isolating v/vs of the Controller for water spray (CD64 → LCA35AA301 & CD70→ LCA36AA301) for de-superheating from CWD04 or from CRT and check the feedback at CWD04 or CRT.

- Close the Up stream manual isolating drain valves (AS113 & AS114) for High capacity PRDS and (AS122 & AS123) for low capacity PRDS line and check the feedback at CRT/ CWD.
- Close the Up stream motorised drain valves (AS115 → LBA33 AA301) for High capacity PRDS & (AS124 → LBA43AA301) for low capacity PRDS line and check the feedback at CRT/ CWD.
- Close the down stream drain valves through Steam Trap Stations (AS 131 to AS 150) of TAS line to Drain header and establish the trap by opening the inlet v/v of the trap and closing the outlet v/v. After the trap is established, open the outlet v/v.
- Gradually put the high capacity controller in service and close the bypass Valve (LBA31AA101).
- Follow the same procedure above for Low capacity PRDS.
- If the following interlocks are satisfied, v/vs may be put in auto mode.

For High Capacity PRDS.

- AS-21 will open when AS-22 > 2% open.
- AS-21 will close and can't be open when AS-22 < 2% open.
- CD-64 will open when AS-22 > 2% open.
- CD-64 will close and can't be open when AS-22 < 2% open.
- CD-65 will be in 'AUTO' when AS-22 > 2% open.

For Low Capacity PRDS.

- AS-31 will open when AS-32 > 2% open.
- AS-31 will close and can't be open when AS-32 < 2% open.
- CD-70 will open when AS-32 > 2% open.
- CD-70 will close and can't be open when AS-32 < 2% open.
- CD-71 will be in 'AUTO' when AS-32 > 2% open.

- Set the TAS header pressure at 11 kg/cm2 and temperature at 2700 C and put the Controllers AS-46 and AS- 56 in auto mode.
- Observe the TAS pressure and temperature is maintaining on AUTO.
- Starting ejector steam v/v & drain v/v before gland steam controller and atmospheric v/v of CRH105 should be opened for getting temperature of PRDS as well as gland steam controller at inlet.
- CRH105 must be closed.
- Check the PRDS flow at DAS / CRT.

Note: If self-TAS is not available opening the interconnection v/v may charge it.

1. PULL CONDENSER VACUUM. (Vac. V . Low Trip at 532 mm Hg. ; Vac. Low annunciation – 608 mm Hg.)
2. PUT HP-LP BYPASS SYSTEM INTO SERVICE (320 & 150 deg. C)
3. INCREASE THE STEAM PARAMETERS TO MATCH HPT METAL TEMP.
4. ROLL TURBINE & SYSCHRONISE.
5. KEEP MACHINE LOAD AT !0.8 MW AS PER RECOMMENDATION.

5. PULVERIZER, PA FAN AND SEAL AIR FAN Strart up:

a. Check the Instrument air pressure is sufficient for boiler area.
b. Unit critical power +24V DC and 110V AC FSSS power supply is available.

For Manual mode of operation for SA, PA, Mill, Feeder and their sub system of a particular group:

Select 'Man' PB of 'Pulveriser Mode Select' either from CWD 02 or from CRT.

a. Seal Air Fan:

Permissive/ Interlocks

- Check the MCC modules are in Service & 'No disturbed' signal present at local control panel.
- Check 415V is available.
- Check the lockout switch is normal.
- Check the Fan is selected for remote operation.
- Check the OFF feedback of Seal Air Fan A is available in DAS/ CRT & CWD.
- Check, no electrical tripping is present for Seal Air Fan A. Pulveriser 'A' OFF feedback is available at CWD/ CRT.Check Suction Filter DP is normal & no high/ low alarm is present at CRT.
- Check seal air fan outlet damper (SL01A- HFW10AA101) is operative from the CWD/ CRT & keep it in closed condition. Check the feedback at CWD/ CRT.
- Seal air damper to PC (HFW11AA101) lines is operative from the CWD/ CRT & keep it in closed condition. Check the feedback at CWD/ CRT.
- Check MFR 1, 2 & 3 are in reset condition.
- Seal airs to Pulveriser inlet damper (HFW12AA101) are in closed condition and verify the feedback from the CWD/ CRT.
- Initiate Seal Air Fan-A (HFW10AA001) start command from CRT/ CWD and verify:

- Check the 'ON' feedback of SA fan at DAS/ CRT & CWD.
- Check the Ampere pegs up & drops down to no load Amps in DAS/ CRT monitor & in CWD Ammeter.
- Open Seal Air Fan outlet damper (SL01A- HFW10AA101) from the CWD/ CRT and check the feedback at CWD/ CRT.
- Verify seal air to Pulveriser inlet damper (HFW12AA101) will open automatically and check the feedback at CWD/ CRT.
- Check seal air to hot PA DP is OK at CRT and at CWD.
- Check Suction Filter DP is changing at CRT/DAS.
- Check Seal air fan O/L pressure at CWD indicator & CRT/ DAS.

Note : Pulveriser release signal to be made available prior to step forward for establishing the mill group. Activity indicated in 'B' & 'C' to be followed first.

b. Pulveriser Lube Oil System:

- Check the Oil tank (HFC10AV001) level at local gauge glass and using the dipstick for adequate.
- Check the manual drain v/v and the filling point of the tank are closed tightly.
- Open locally the manual outlet v/v (HFC10AA001) of the tank.
- Open the manual suction v/v (HFC15AA001) of Lube oil pump A locally.
- Keep close the manual suction v/v (HFC15AA004) of Lube oil pump B locally.
- Keep close the manual discharge v/v (HFC15AA003) of Lube oil pump A and the manual discharge v/v (HFC15AA006) of Lube oil pump B locally.
- Check for the isolating v/vs. of oil line (either of the two Lube oil cooler is in service HFC15AA007 & HFC15AA009 for cooler A or HFC15AA008 & HFC15AA010 for cooler B).

- Check for either of the two Lube oil cooler is in service (DM cooling water inlet and outlet isolating valves are open - See the procedure at DMCW Boiler and check locally that the flow is already established).
- Check whether, the 415V supply to Lub oil pumps is healthy.
- Check whether, all the MCC modules are in Service (A & B).
- Lockout switches for all the pump motors are normal (released condition) and have been selected for remote operation.
- Put the Lube oil pump A & B in 'MAN' mode.
- Check the 'OFF' feedback of Lube oil pump A & B in DAS / CRT and unit control panel (CWD02).
- Ensure that the alarm 'Pulveriser-A Lub oil pressure V. low' is appearing in DAS/ CRT.
- Ensure that the alarm 'Pulveriser-A Lub oil flow low' is appearing in DAS/ CRT and also in unit control panel (CWD02).
- Ensure the Seal Air System is OK (from step A).
- Start the Lube oil pump A (HFC15AN001) either from CRT or from UCP (CWD).
- Open the manual discharge v/v (HFC15AA003) of Lube oil pump A locally.
- Check the discharge pressure locally (HFC15CP001).
- Check the pump 'ON' Feedback in the CRT monitor and in CWD.
- Stop Lube oil pump A either from CRT or from CWD.
- Check the discharge pressure locally (HFC15CP001).
- Check Lube oil pump B should not start.
- Check the 'OFF' Feedback in the CRT monitor and in CWD.
- Keep open the manual suction v/v (HFC15AA004) of Lube oil pump B locally.
- Start the Lube oil pump B (HFC15AA005) either from CRT or from UCP (CWD).
- Keep open the manual discharge v/v (HFC15AA006) of Lube oil pump B locally.
- Check the discharge pressure locally (HFC15CP001).
- Check the pump 'ON' Feedback in the CRT monitor and in CWD.
- Stop Lube oil pump B either from CRT or from CWD.
- Check the discharge pressure locally (HFC15CP001).
- Check Lube oil pump A should not start.
- Check the 'OFF' Feedback in the CRT monitor and in CWD.
- Keep the Lube oil pump A in MAN mode & Lube oil pump B in AUTO mode.
- Check the Lube oil pump B will start instantly due to low discharge pressure.
- Put the Lube oil pump A In AUTO mode.
- Check that the alarm 'Pulveriser-A Lub oil pressure V. low' is disappearing in DAS/ CRT.
- Check that the alarm 'Pulveriser-A Lub oil flow low' is disappearing in DAS/ CRT and also in unit control panel (CWD02).
- Check that locally the lub oil flow is established and also in CRT.
- Check the Lube oil pressure is OK and > 0.8 ata. (Normally pressure should be ≅ 1.8 Kg/ cm2 when one pump is running.) at the CRT.
- Check the oil temperature is not high locally and in CRT.

c. Pulveriser Gas System:

   a. Feed the N2 Gas slowly into the Gas line of the Mill & maintain the pr. at 40 Bar.
   b. Keep the oil pressure 10 bar above the gas pressure by using the hand pump (Ram).
   c. Check that N2 Gas pressure is not low (no alarm is present at CRT/ DAS).

For further proceeding towards the PA Fan starting Mill Release Interlock is required.

Mill Release Interlock: Following conditions to be fulfilled.

- Check the PA General Shut off dampers (HFE21AA104 & 105) is operative from CWD/ CRT and keep it in close.
- Check, PA Cold Air damper (CAD2A-HFE22AA201) is operative from the CWD/ CRT & keep it in < 5% opened condition. Check the feedback at CWD/ CRT.
- Check, Coal Burner manual isolation v/v 1, 2, 3 & 4 (HFC12AA201, HFC12AA202, HFC11AA201 & HFC12AA202) are in open condition.
- Check, RC Feeder outlet damper (HFC10AA101) is operative from the CWD/ CRT & keep it in opened condition. Check the feedback at CWD/ CRT.
- Check, PA Cold Air Gate (CAD1A-HFW22AA201) is opened locally. Check the feedback at CWD/ CRT.
- Check, RC feeder inlet gate (HFB10AA301) is full open.
- Check, Hot air shut off gate (HAD1A- HFE21AA103) is operative from the CWD/ CRT & keep it in opened condition. Check the feedback at CWD/ CRT.
- Check pulveriser gas loading pressure 'not very low 'and 'not low' is present.
- Check, Pulveriser lub oil is ok.

d. PA Fan A Lube Oil System:

i. Check the Oil tank level at local gauge glass for adequate.
ii. Check there is no alarm of "Oil tank level low (HFE11CL105)" in DAS/ CRT (set at < 50%).
iii. Check for either of the two Lube oil cooler is in service (DM cooling water inlet and outlet isolating valves are open - See the procedure at DMCW Boiler and check locally that the flow is already established).
iv. Check, the alarm 'PAF-A DP across Lub oil Filter high > 0.6 ata. (HFE11CP101)' is not appearing in DAS/ CRT and CWD alarm facia.
v. Check whether, the 415V supply to Lub oil pumps is healthy.
vi. Check whether, all the MCC modules are in Service (A & B).
vii. Lockout switches for all the pump motors are normal (released condition) and have been selected for remote operation.
viii. Put the Lube oil pump A & B in 'MAN' mode.
ix. Check the 'OFF' feedback of Lube oil pump A & B in DAS / CRT and unit control panel (CWD).
x. Ensure that the alarm 'PAF-A Lub oil pressure low < 0.4 ata' is not appearing in DAS/ CRT and CWD alarm facia.
xi. Start the Lube oil pump A (HFE11AP001) either from CRT or from UCP (CWD).
xii. Check the discharge pressure locally (HFE11CP106).
xiii. Check the pump 'ON' Feedback in the CRT monitor and in CWD.
xiv. Stop Lube oil pump A.
xv. Check the discharge pressure locally (HFE11CP106).
xvi. Check Lube oil pump B should not start.
xvii. Check the 'OFF' Feedback in the CRT monitor and in CWD.
xviii. Start the Lube oil pump B (HFE11AP002) either from CRT or from UCP (CWD).
xix. Check the discharge pressure locally (HFE11CP106).
xx. Check the pump 'ON' Feedback in the CRT monitor and in CWD.
xxi. Stop Lube oil pump B.
xxii. Check the discharge pressure locally (HFE11CP106).
xxiii. Check Lube oil pump A should not start.
xxiv. Check the 'OFF' Feedback in the CRT monitor and in CWD.

xxv. Keep the Lube oil pump A in MAN mode & Lube oil pump B in AUTO mode.
xxvi. Check the Lube oil pump B will start instantly due to low discharge pressure (< 0.6ata).
xxvii. Put the Lube oil pump A In AUTO mode.
xxviii. Check the Filter DP locally (HFE21CP107).
xxix. Check the Lube oil pressure is OK (HFE21CP103) and > 0.8 ata. (Normally pressure should be ≅ 1.8 Kg/ cm2 when one pump is running.)

e. Primary Air Fan A:

Permissive/ Interlocks

- Check the 6.6 KV voltage is available for PA Fan-A.
- Check the Breaker is in Service and DC control supply is 'ON'.
- Check the lockout switch is normal.
- Check the Fan is selected for remote operation.
- Check the OFF feedback of PA Fan-A in DAS/ CRT & CWD.
- Check, no electrical tripping is present for PA Fan-A.
- Check MFR 1, 2 & 3 are in reset condition (no MFT).
- Check Pulveriser discharge v/v 1 & 2 are operative from the CWD/ CRT & keep it in open condition. Check the feedback at CWD/ CRT.
- Check, Seal Air Fan A is running and Seal Air Fan dampers are open at CRT/ CWD.
- Check seal air to hot PA DP is OK at CRT and at CWD.
- Check PA Fan A lub oil system is healthy.
- Check 'Pulveriser release available' is available.
- Check, PA Fan Inlet vane (PAD1A-HFE21AA102) is operative from the CWD/ CRT & keep it in minimum condition. Check the feedback at CWD/ CRT.

Check PA FAN A ready lamp is available at CRT/ CWD.

- Check, coal Elevation Start Permit is available at CWD/ CRT.
- Check, Pulveriser Ignition Permit is available at CWD/ CRT.
- Either boiler load > 30% and adjacent Mill feeder is proven > 50% OR
- Elevation AB 3 out of 4 nozzle v/vs is open. (This logic is true for Mill A & B. For Mill C, D elevation CD and for Mill E & F elevation EF is required.)
- Check the PA Fan A Motor Winding temperatures (HFE21CT107- HFE21CT112) & Bearing temperatures (HFE21CT119, HFE21CT103) are in Ambient in DAS/ CRT display.
- Check the PA Fan A Fan Bearing temperatures (HFE21CT101 & HFE21CT102) are in Ambient in DAS/ CRT display.
- Check the PA Fan A Fan Bearing vibrations (HFE21CY101-HFE21CY104) are showing zero value in DAS/ CRT display.

- Initiate PAF-A start command from CRT/ CWD and verify:-
  - Check the 'ON' feedback of PA fan at DAS/ CRT & CWD.
  - Check the Ampere pegs up & drops down to no load Amps in DAS/ CRT monitor & in CWD Ammeter (amps will be normalise after 20 secs from the issuance of the start command.).
  - Check Mill outlet temperature control is released for 'auto'.
  - Open the PA General Shut off dampers (HFE21AA104 & 105) from CWD/ CRT and check the feed back at CWD/ CRT.
  - Check, Hot air damper (HAD2A- HFE21AA101) is operative from the CWD/ CRT & keep it in closed condition. Check the feedback at CWD/ CRT.
  - Open PA Cold Air damper (CAD2A-HFE22AA201) from the CWD/ CRT > 5%. Check the feedback at CWD/ CRT.
  - Open PA Fan Inlet vane (PAD1A-HFE21AA102) 5% from the CWD/ CRT. Check the feedback at CWD/ CRT. Check the PA Fan Amps at CWD/ CRT.
  - Put PAFA HAD (HFE21AA101) at 'AUTO' position.
  - PAF CADA (HFE22AA101) at 'AUTO' position to regulate Temp.

- Motor loading is normal.
- Motor winding Temp. is normal.
- Fan and motor bearing Temperatures are normal

f Pulveriser A:

Permissive/ Interlocks

1. Check the 6.6 KV voltage is available for Pulveriser-A.
2. Check the Breaker is in Service and DC control supply is 'ON'.
3. Check the lockout switch is normal.
4. Check the Pulveriser is selected for remote operation.
5. Check the OFF feedback of Pulveriser-A in DAS/ CRT & CWD.
6. Check, no electrical tripping is present for Pulveriser-A.
7. Check MFR 1, 2 & 3 are in reset condition (no MFT).
8. Pulveriser inerting line is charged and controller is in 'Auto'.

The following permissive should be checked at CWD/ CRT before starting the Pulveriser :

1. Pulv. A Coal elevation start permit is healthy.
2. Pulv/Feeder start permit is healthy.
3. SA/ Hot PA DP is OK. (Seal air fan (HFW10AN001) is running and damper (HFW10AA101) is open.)
4. Check both the discharge valves (HFC11/12 AA101) are operative from the CWD/ CRT and keep it in open condition. Check the feedback at CWD/ CRT.
5. Pulv A outlet temperature is not high (< 93 deg C) and not very low.
6. 'No Auto Unsuccessful start' is present.
7. PA Cold Air Gate (CAD1A-HFW22AA201) is opened locally.
8. Feeder I/L gate (HLB10AA301) is in opened condition.
9. Coal Burner manual isolation v/v 1,2,3 & 4 (HFC12AA201, HFC12AA202, HFC11AA201 & HFC12AA202) are in open condition.
10. Check 'Pulveriser release available' is available.
11. Check 'No Pulv. Trip' signal is available.
12. Check 'Pulv. Ready' is available.
13. The PA General Shut off dampers (HFE21AA104 & 105) are open.
14. PA Fan is 'ON' (for > 20 sec).
15. Check ' Pulv. Ignition permit' is available.
16. Pulv A Lub.oil pump (either HFC15AN001or 002) in service and lub oil pr(>1.4kg/cm2) and flow is normal.
17. Check the total air flow > 40% at CWD/ CRT.
18. Check the Pulveriser A Motor Winding temperatures (HFC10CT106- HFE21CT111) & Bearing
19. temperatures (HFC10CT104 & HFC10CT105) are in Ambient in DAS/ CRT display.
20. Check the Pulveriser A Bearing vibrations (HFC10CY101-HFC10CY102) are showing zero value in DAS/ CRT display.

Initiate Pulverizer A start signal from CRT/ CWD and verify:

- Check the 'ON' feedback of Pulverizer A at DAS/ CRT & CWD.
- Check the Ampere pegs up & drops down to no load Amps in DAS/ CRT monitor & in CWD Ammeter.
- Pulverizer seal air valve open
- Open Hot air gate
- Put PA vane control in auto.
- Put Pulverizer outlet temperature control (HAD & CAD) in auto.
- Check the Pulveriser A Motor Winding temperatures (HFC10CT106- HFE21CT111) & Bearing temperatures (HFC10CT104 & HFC10CT105) are changing in DAS/ CRT display.

- Check the Pulveriser A Bearing vibrations (HFC10CY101-HFC10CY102) are changing in DAS/ CRT display.

g FEEDER A:

The following permissive should be checked at CWD/ CRT before starting the Feeder:

- Check the 415V voltage is available for Feeder-A.
- Check the MCC is in Service and DC control supply is 'ON'.
- Check the lockout switch is normal.
- Check the Feeder is selected for remote operation.
- Check the OFF feedback of Feeder-A in DAS/ CRT & CWD.
- Check, no electrical tripping is present for Feeder-A.
- Check MFR 1, 2 & 3 are in reset condition (no MFT).
- Pulveriser A is 'ON'.
- Check pulveriser ready signal is available.
- Mill motor current is low.
- Check feeder speed demand is in minimum condition.
- Check HAG is in open condition.
- RC feeder outlet dampers are in open condition.

All the Permissive required to start the Pulveriser is also required to start the Feeder.

- Initiate FDR A start signal from CRT/ CWD.
- Check the 'ON' feedback of Feeder A at DAS/ CRT & CWD.
- Verify the Coal feed rate at CWD/ CRT. (If within 5 sec the Coal On signal not available, feeder will trip.)
- Check the Flame condition at AB elevation.
- Check the SADC system is modulating.
- Increase the Feeder command by 5% and check the feeder amps is increasing. Also check the coal flow rate is increasing and the total coal flow is integrating at CWD/ CRT.
- Transfer coal feeder A to auto
- Check the PA flow, PA I/L temperature, Mill O/L temperature, Mill Pressure, Mill to PA DP, % opening of HAD & CAD, PA vane position at CWD/ CRT.
- Annunciator to be cleared

Similar procedure to be followed for other Mill group starting.

6. Increase load to 30% - 50%

i. Increase load target to 30% (63MW)

a. Check the following :

- Both the Draft Fans are running.
- Two Coal Mills are running for steaming the boiler.
- All other auxiliary equipments are capable for raising 30% of rated load.
- All LP heaters are in service.

b. Transfer boiler pressure controller to auto and verify :

- Both the Draft Fans are put on auto.
- Transfer pulverizer mode to auto
- Check PA control is in "AUTO" mode
- Feed water system is in auto.
- Adjust Load increasing set point .
- Select the mode of control for increasing the load.

c. Put the Load Setter to 63 MW / or

d. Increase manually Machine load to 63 MW gradually and observe all the load bearing equipments are sharing proportionate loads.

ii. Increase load to 50% (105MW)

- Put the third Coal Mill in service to avoid overloading of Coal Mills.
- Ensure two BFPs and two CEPs are running on auto control.
- Ensure FW system is on high load control.
- Ensure all HP heaters are in service.
- Check PA control is in "AUTO" mode
- Feed water system is in auto.
- Adjust Load increasing set point .
- Select the mode of control for increasing the load.
    - Put the Load Setter to 105 MW /or
    - Increase manually Machine load to 105 MW gradually and observe all the load bearing equipments are sharing proportionate loads
    - Annunciator to be cleared

iii. FOLLOWING ACTIONS ARE TO BE TAKEN WHILE INCREASING LOAD :

- At 50 MW load :
    a. Put LP Heaters in service,
    b. Put UAT into service.
    c. Close HP bypass valves.
    d. Change over Deaerator pegging from TAS to CRH.
- At 80 ~ 90 MW load LP bypass valves are closed automatically.
- Put the HP Heaters in service at 90 MW load.
- Transfer Deaerator pegging extraction steam from TAS to CR at 60 MW load and CR to Extraction –4 at 90 MW load.

7. Loading to 100% of NR

i. Start 4th. pulverizer/coal feeder
ii. Stop CD elevation L.O burner when 3rd coal feeder feed rate> 60% and flame is stable
iii. Check gland seal steam diverting valve is transferred to #1 LP HTR from condenser
iv. Increase load up to 210 MW gradually and observe :

- Boiler parameters.
- Deaerator level
- BFP parameters.
- Condenser vacuum.
- Turbine brg. lube oil temp., bearing vibration, diff. expansion etc.
- Gen. Cooled Gas temp.
- Generator winding Temp.

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ROUTINE CHECKING OF THE BOILER

From UCR

Boiler drum pressure (at 210MW it remains 160kg/cm² approx.)
Boiler drum level (normal level is ± 0 mm of coil)
MS/Reheat temp. (normal value ~ 537°C/537 °C
Condition of ASLD (ASLD means a steam leakage detector)
Total coal consumption
Hourly make up water consumption
Position of burner tilt
Condition of SADC (SADC means secondary air damper control
Condition of furnace draft
Availability of burners
Condition of boiler Attemperation

Local checking :

- Whether any oil leakage through the burner
- Whether any steam leakage is there
- Local burner tilt position
- Whether any safety valve is simmering or not
- Flame condition through the manhole (particularly if furnace disturbs)
- Status of Attemperation valves.
- Amount of water draining through CBD tank and amount of steam coming out through the vent; it more check the drain valves to detect passing.
- If make up water consumption is more then check the boiler for any tube leakage.

Routine checking of boiler auxiliary equipments cooling system DMCW (Boiler) Pumps.

From UCR :
Motor amps; normal value -35 approx.
Pump discharge pr.; normal value – 4 kg/cm². At ≤ 3.5 kg /cm² discharge pr. low appears and the standby Pump takes start.

Local checking
Whether any abnormal sound with Pump or motor
Whether any gland leakage of the Pump
Whether any temp. of motor and Pump bearings by hand filling.
Ensuring the open condition of suction and disch. valve of the stand by Pump.

NB : Standby Pump should be lined up and on auto and its MCC should be on & LOS should be in released condition.

Emergency operation

If the DMCW (Boiler) Pump which is in running condition trips the standby Pump will take start on auto and then no probe will be there but if the standby Pump is NA or if the Pump trips due to DMCW tank level low (wherefrom the Pump, receive their suction) then boiler side equipment will starve due to want of cooling water and within 10-15 minutes (depending upon the ambient temp.) the equipment will start tripping due to rise in bearing. temp. or working oil (IDF only) temp. So, within this period attempt is to be made to normalize the situation to avoid tripping of the running equipments as well as the machine.

Routine checking of scanner fans:

1. AC scanner fans during running it draw 5 amps and develop disch. Pr. of 225mm of wcl. If the disch. Pr. drops below 125mm of wcl then DC scanner fan takes start automatically. If the AC scanner fan trips due to some other reason then also the DC scanner fan takes start.
2. DC scanner fan draws 7 amps at running condition. Both the fans take suction from FD fan disch. Line. In absence of FD fan (during boiler's hot box up condition) it takes air from the atmosphere. If the discharge pr of running scanner fan becomes low and dp across the scanner fan filter becomes high then strainer is to be changed and the choked filter needs cleaning.
3. As the scanner fans cools down the costly flame scanners, so without scanner fan do not allow running the boiler more than 5-10mins which will damage the scanner and ultimately the boiler will trip with flame failure.

NOTE : For all available equipment beakers are should be at rack in and remote condition, MCC should be at on and remote condition and LOS should be at released condition. This is also a part of checking.

Oil burners
All available oil burners must be cleaned and clamped condition and should be kept at remote position so that during emergency these burners can be inserted instantaneously.

Shut down procedure of boiler

1. Load down : 2% / min (i.e. 4.2 MW/min)
2. At 100-90MW(Dead pegging Ex-4 to CRH)
3. At 83 to 60 MW load (LP bypass CV opens automatically)
4. At 60MW (Dead pegging from CRH to Aux PRDS)
5. At 60MW to 40 MW (HP heaters are to be taken out of service manually)
6. At 40MW to 20MW (LP heaters are to be taken out of service).
7. At 10MW (trip turbine through TLR)
8. Up to 110-100 MW m/c load, load down can be done on CMC with three mill operation (without oil support) but as m/c load comes down the turbine inlet steam pr. set pt. is to be reduced accordingly.
9. At about 110MW M/C load m/c is to be put on TFM, before cutting out the third mill, 4 to 6 oil burners are to be placed in service and then after as gradually coal feeding rate decreases, oil support is to be increased both in no. and pr. (ultimately 8 to 10 nos. oil guns with a pr. of 6 to 8 Ksc will be there).
10. At 10MW m/c load there will be only oil firing without coal mill in service (with oil support it is better to allow the coal mills to be empty and if possible also make the coal feeder inlet gate connected to the coal bunker).
11. At 10MW m/c load when turbine is allowed to trip, still then HP/LP bypass is open and vacuum is on. Afterwards HPLP bypass system is to be closed slowly keeping an eye to the boiler drum water level.
12. To break the vacuum;
13. stop main ejector
14. open the vacuum breaker
15. close gland sealing control valve at 140mm of Hg
16. TAS put out of service
17. Boiler O/L valve closed
18. MS line drain valve open
19. trip MFR
20. FO shut off valve will get closed automatically
21. purge the boiler
22. take water in boiler drum by running BFP up to 10 to 12 ports
23. stop ID & FD fans after purging is over
24. Keep one draft set running if instructed to cool down the boiler to attend any main. Work.
25. Again take water in boiler drum up to 10 to 12 when water level falls down to 1 or 2 ports (repeat the procedure until the boiler drum pr. falls down to 5 Ksc.
26. At 5 Ksc drum pr. hot draining of the boiler is done for dry storage of the boiler to allow B/M to attend any maintenance work like boiler tube leakage repairing etc.
27. procedure of hot draining
28. open drum vents
29. open water side drains (i.e. low point drains)
30. After completion of draining of water through water side drains open steam side vents and drains if decision is there to keep the boiler water intact without draining then only open the vents when boiler drum pr. is 1 to 2 kg pr. If there is some other reason of unit shut down except boiler work; then after completion of boiler work boiler is allowed to fill up with alkaline water (if mixing ammonia and hydrazine with the filling water as prescribed by chem.. lab) either by running BFP or CTP. In this case boiler drum is also allowed to be flooded and water is allowed to go to superheaters (all drains are kept closed and all vents are kept open). This is called wet storage of the boiler.

N.B. : After hot draining again water is taken to the boiler drum when drum metal temp. drops below 80°C

Emergency operation (case 1)

Boiler drum level low; it may happen due to the following reasons :

- Tripping of one of the two running BFPs (when third one is not available)

- Malfunctioning of scoop of a running BFP towards the closing direction
- Malfunctioning of FCS valve which is in service (towards closing direction)
- Sudden reduction of m/c load
- Sudden tripping of one or more coal mill / burner
- Sudden tube failure of water wall system of the boiler
- Inadvertent opening of IBD/ low point drain valves.

Plant response

drum level low alarm at (-125mm of wcl)
Drum level very low alarm at (-225 mm of wcl) and the m/c trips.

Operation action at UCR

- On CMC due to tripping of a running BFP, the standby BFP which is on auto takes start and as such no abnormality occurs.
- If the 3rd BFP is NA then m/c load automatically comes down to 125MW and the top most mill also trips (if 4 mills are in service).
- But if the m/c is on TFM/BFM and the third BFP is NA then m/c load is to be brought down to 140MW approx by tripping the top most mill group and lowering down the m/c load set point. Close watch is to be paid on steam parameters drum level, running BFP amps furnace 02 % etc.
- If on auto any running BFP scoop or FCS valve malfunctions attempt is to be made to switch over the scoop or FCS valve from auto to man mode and increase accordingly. If not possible, then m/c load is to be reduced as early as possible.
- If no abnormality with BFP or FCS has been observed then check the boiler for tube leakage or drain valve opening etc.

Local checking :

Check the tripped BFP or malfunctioned scoop of running BFP or defective (FCS valve and after rectification of the same normalize the unit load.

Emergency operation (case -2)

Drum level high; it may happen due to the following reasons :

- Malfunctioning of FCS valve scoop of the running BFP at upper direction
- Sudden increase of m/c. load
- Sudden increase of firing rate
- Sudden opening of HP/LP bypass valves.

Plant response:

Drum level high alarm at (+125mm of wcl)
Drum level v.v. high alarm at (+225mm of wcl) and m/c trips.

Operation action at UCR:

- Open boiler emergency drains like EBD, CBD, and IBD depending upon the gravity of the situation.
- Switch over to drum level control through BFP scoop ignoring FCS valve (if FCS valve gets wide open)
- Switch over the defective BFP scoop or FCS valve in man mode to control the feed flow and reduce the drum level.

N.B : If the m/c does not trip at drum level v.v low / v.v high trip the unit without hesitation as it may cause severe damage of the unit.
At very very low drum level flow through down comers may be affected which will lead water wall tube failure.
At very very high drum level may cause water carry over which will seriously damage the turbine, superheaters, M.S. line etc.

Emergency operation (case -3)

High furnace pr.; it may happen due to the following reasons :

- At tripping of either of running ID fans if the corresponding FD fan does not trip.
- Sudden opening of regulating vanes of a running FD fan
- closing of damper in flue gas path
- starting of loaded coal mill with excess PA flow
- Furnace water seal broken
- Unequal burner tilt at corners
- Manholes at ESP or elsewhere in the flue gas path suddenly gets open

Plant response;

if furnace pr. touches (+75mm of wcl) furnace pr. high alarm appears
If furnace pr. touches (+150mm of wcl) furnace pr. v.v high appears and unit trips.

Operation action (at UCR)

- Check draft readings whether any damper is closed or not, if so check damper open display and correct the defect .
- check vane control mechanism of fans and corrective measures should be taken accordingly.
- If any ID fan trips reduce m/c. load, stabilize unit with one IDF and restart the other after proper checking /rectifying the cause of tripping.
- Check the combustion regime for any defect at SADC, burner tilt etc. and if any trouble is found corrective action is to be taken accordingly.
- Check furnace seal, seal may get broken due to low or interrupted water supply, if so re-establish the seal quickly (if broken) and check the water flow through the overflow drain.

If sudden starting of the mill causes the furnace pr. high wait for few minutes, it may get normalized gradually.

Local checking

- Check the manholes; if some of them are found open close them.
- Check the dampers at flue gas path for confirming their at open condition.
- Check IDF vane mechanism links and if any abnormality is seen please inform main dept to rectify it.
- check the burner tilt position locally and set right them
- check the furnace seal water flow

Emergency operation (case -4)

Low furnace pr.: it may happen due to the following reasons :

- Running IDF auto control failure
- Running IDF vane control failure to make it wide open
- Sudden load throw off
- Sudden decrease in air input or tripping of either of running two F.D.Fans

Plant response:

- Disturbance of flame condition
- At (-100mm of wcl) furnace pr. low appears.
- At (-175mm of wcl) furnace pr. v.v. low appears and unit trips.

Operation action:

- Switch over IDF auto control to man mode to bring back the normal situation
- Check the IDF vane control mechanism
- Check the total air flow and correct it accordingly if necessary
- Restart the F.D.Fan, if fan got tripped.

Emergency Operation (case -5):

If one of the running I.D.Fans trips; it may happen due to the following reasons

- IDF motor protection acted (i.e. thermal overload, earth fault etc.)
- Supply failure of the motor feeding BUS

- Low lub. Oil pr. (due to tripping of LOPs low lub oil level, oil leakage etc.)
- High bearing temp of motor or fan
- Failure of cooling water system
- High vibration of fan bearing

Plant response

- Tripping of the corresponding FDF
- Tripping of the top most mill group (if four mill operation is there)
- Disturbance of the furnace
- Disturbance of drum level

Operation action

- On CMC automatically m/c load comes down to 125MW and as such except monitoring the parameters nothing can be done.
- But if the m/c is on TFM or BFM or MAN mode, during tripping of running IDF, coal feeding rate, total air, O_2% etc. are to be adjusted manually as early as possible corresponding to 150MW m/c. load approximately. So that prolonged overloading of the running IDF and FDF can be avoided, but during this operation a close watch is to be provided over the drum level and turbine parameters as well.
- Continuous running rating of a IDF is 137 amps though for safety it is maintained 110 to 120 amps of the single running IDF to generate 170 to 180MW on TFM.

Local checking:

Find out the cause of tripping of the IDF, if the problem is minor run the IDF after the rectification, but if the problem is major then inform the maint. dept. accordingly.

Emergency operation (case-6):

If one of the running F.D.Fans trips: It may happen due to the following reasons causes of tripping are almost same as stated in IDF tripping at case – 5 .

Plant response:

Tripping of the topmost mill gr. (if four mill operation is there)
Disturbance of furnace draft
Disturbance of drum level

Operation action:

On the CMC automatically m/c load comes down to 125MW and as such except monitoring the parameters nothing can be done.

But if the m/c is on TFM, BFM or MAN mode, during tripping of a running FDF, coal feeding rate, total air, O_2% etc. are to be adjusted manually as early as possible corresponding to150MW m/c load approximately. So, that prolonged overloading of the running FDF can be avoided. During the operation a close watch is to be provided over the drum level and turbine parameters as well.

Local checking:

Find the cause of tripping of the F.D.Fan, if the prob. is minor restart the fan after rectification, it probe is major please inform maint. department accordingly.

Emergency Operation (Case-7)

Tripping of any running PAF or coal mill; it may happen due to the following reasons :

a. Motor protection acted
b. Supply failure of the feeding BUS of motor of PAF/coal mill or 415V motors of LOPs
c. High bearing temp. of the motor or PAF
d. Low lube oil pr.
e. Failure of cooling water system
f. High vibration of PAF Bearing. / mill

Plant response:

Tripping of a P.A.Fan also initiate tripping of the corresponding mill group.
On CMC m/c load comes down to 168MW automatically (if the fourth mill trips) & 125MW (If the 3rd mill trips).
On TFM m/c load comes down automatically corresponding to the feeding rate

The running coal mills.
M.S. temp. and pr. automatically comes down to some extent
Furnace disturbance
Drum water level disturbance

Operation action :

If the machine is on CMC and system demand is high, then consulting with shift charge engineer, change over the mode of operation from CMC to TEM & increase coal feeding of the running mills to generate max. Power as per capacity.

Tray to investigate the cause of tripping of the mill gr. As early as possible if the probe is minor then starts again the mill gr. After rectification of the same.

If the probe is major, then cut in the start by mill group and increase the m/c load accordingly.

Local checking:

Try to find out the exact cause of tripping of the mill group, with a local checking and report to the respective maint. dept. accordingly, if the problem is major.

Check the performance of the newly cut in mill group locally if it is being taken in the system.

Emergency Operation (Case-8)

Water wall tube failure; it may happen due to the following reasons:-

- Starvation of water wall
- Flange impingement on water wall tubes (may be due to defective burner tilting).
- Blockage/corrosion / salt deposition of water wall tubes.
- Soot blowing steam impingement on water wall tubes
- Improper circulation for prolonged opening of low point drain –namely IBD.

Plant response :

- Hissing sound of steam leaking from the boiler is noticeable a few hours in advance before the situation concerns.
- Unstable flame, fluctuation of draft etc.
- Higher feed water consumption from make up system or higher feed flow is required for a given steam generation.
- Overloading of I.D.Fans.
- Annunciation of ASLD at UCP facial /CRT for the particular area of the boiler.

Operation action:

At first, confirm diagnosis of tube failure is to be done, then start to reduce m/c load immediately. It is better to trip out the unit before damaging becomes serious.

Local checking:

To avoid tube failure or to defect the leakage early a close watch should be given to the following criteria :

- Check the low point drain header valves are fully tight.
- Furnace is stable and there is no impingement of flame to the furnace wall.
- To listen the furnace to defect steam leakage noise
- Check the hourly water consumption
- If the boiler tube leakage is confirmed try to locate the leaked tube as it would help to rectify the problem earlier.

Emergency Operation (Case-9)

Re-heater / superheater tube leakage: It may happen for the following reasons:-

- Sustained higher metal temp. at the time of hot start up.
- Erosion of tubes due to high excesses air
- Erosion due to soot blowing

- Salt deposition due to high water level in drum; poor quality spray water, poor quality of water during hydraulic test.
- Inadequate flow due to open superheater drains.

Plant response

- All 5 systems (a) to (e) as stated water wall tube failure. (In addition to that)
- Unexpected drop of flue gas temp. in the affected region
- Superheat or Reheat Temp. drop.
- High superheat or Reheat metal drop.

Emergency Operation (Case – 10)

Economiser tube leakage: It may happen due to ash erosion of the tubes

Plant response

All five symptoms (a) to (e) as stated at water wall tube failure (In addition to that).
Ash solidification in economizer hoppers
Water leakage from economizer hopper

Operation action:

For Superheater / Reheater / Economiser tube leakage operation action is same as water wall tube leakage.

Local checking:

Same as water wall tube leakage. In addition, please check the dryness of economizer hopper regularly.

Emergency Operation (Case – 11):

High superheat / Reheat temp; it may happen due to the following reasons:
Excess air
High burner tilting
Cut in of top elevation mill at loaded condition
Sudden increase of firing rate
Poor coal quality which burns at upper elevation
Low feed water temp. (may be due to absence of HP heaters).
Soot deposition at water wall
Inadequate spray form Attemperation systems.

Plant response :

Alarm of high superheat temp at 545°C at HP turbine inlet.
Alarm of very very high superheat temp at 565°C at HP turbine inlet and turbine trips.

Operation action:

Check air flow and reduce the same if possible.
Check burner tilt and make it downward if necessary
Initiate soot blowing
Change over of coal mill from upper to lower if necessary.
Check sprays control valves for open position.

Emergency operation (case – 12)

Low superheat/Reheat temp; It may happen due to the following reasons:

- Dirty reheater / superheater due to soot deposition
- Inadequate air flow
- Higher Attemperation spray
- Sudden tripping of higher elevation coal mill
- Too high feed water temp.

Plant response:

- For low superheat temp steam at HPT inlet low appears at 450°C
- For vv. Low superheat temp. steam temp at HPT inlet v.v. low appears at 430°C and turbine trips.

Plant response :

check air flow and increase if necessary
Check feed water temp; if possible rectify it,
Check spray control and reduce spray, if necessary or manual mode.
Check burner tilt; if possible put them upward manually.
Changeover the mill group from lower to upper if possible.

N.B. : (a) Burner tilt mechanism is meant for controlling reheat temp. mainly; while Attemperation spray system is for controlling super-heater temperature. Reheat temperature is not affected by low feed water temp.

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COMBUSTION THEORY, CONSTRUCTIONAL DETAILS P.F, OIL BURNER, SPECIAL FEATURES OF COAL & OIL FIRING SYSTEM.

In the field of power generation useful heat is produced by combustion, which may be defined as the rapid chemical combination of oxygen with the combustible elements of a fuel. The common fuels are, coal, oil, gas, wood etc and they have only three elements constituent carbon, hydrogen, and sulfur which units with oxygen from air to produce heat after ignition. Most of the fuels the elemental constituents are carbon and hydrogen since the percent of sulfur is so low as to be negligible in producing heat.

To achieve complete combustion , that is the combination of the combustible elements and compounds of a fuel with all the oxygen which they can utilize sufficient space ,time mixing or turbulence and a temperature high enough to ignite.
The combustible elements and their compounds found in fuels used in the commercial generation of heat as well as their molecular weights and combustion constituents including heat value are listed in the table no --1. The non combustible elements and compounds involved in combustion are also listed in table no --1. Oxygen combines with combustible elements and compounds in accordance with the law of chemistry and various substances involved always combine in fixed proportions by weight. Typical chemical reactions frequently encountered in the commercial production of heat are given in the table no -2. These chemical equations are based on the assumption that the reaction is complete and that the exact amount of oxygen required is utilized.

Principles involved in combustion :
In a boiler furnace (Where no mechanical work is done) the heat energy involved from the union of combustible elements with oxygen depends upon the ultimate products of combustion and not upon any intermediate combinations that may occur in reaching the final result and this combustion generally followed the second law of Berthelot.
A simple demonstration of this law is the union of 1lbs of carbon with oxygen to produce a specific amount of heat (About 14100 BThU)
The union may be in one step to form the gaseous product of combustion CO under certain suitable condition the union may be in two steps first to form CO, producing much smaller amount of heat (around 4000 BThU) and second the union of CO with oxygen to form CO and releasing 10100 BThU. However the sum of heats released in these two steps equals to 14100 BThU.
The carbon may enter into these two combinations with oxygen is of outmost importance in the design of combustion equipment, firing methods must assure proper and complete of the fuel and the oxygen. Failure to meet this requirement will result in appreciable losses in combustion efficiency and heat potential because of unburnt combustibles.

Measurement of the heat of combustion : .
In boiler practice the heat of combustion of a fuel or calorific value frequently referred to as the "fuel Btu" value is the amount of heat expressed in Btu generated by the complete combustion or oxidation of a unit Wt

of fuel. The amount of heat so generated is a constant for any given combination of combustible elements and compounds and in with Berthelot's second law is not affected by the manner in which combustion takes place providing it is complete.

Common chemical reactions of combustion: (TABLE-2)

Sl.No.	Combustible			Reaction
1.	Carbon (to CO)	$2C + O_2$	=	$2CO + Q$
2.	Carbon (to CO_2)	$C + O_2$	=	$2CO_2 + Q$
3.	Carbon-monoxide	$2CO + O_2$	=	$2CO + O_2 = 2CO_2 + Q$
4.	Hydrogen	$2H_2 + O_2$	=	$2H_2O + Q$
5.	Sulfur (to SO_2)	$S + O_2$	=	$SO_2 + Q$
6.	Sulfur (to SO_3)	$2S + 3O_2$	=	$2SO_3 + Q$
7.	Methane	$CH_4 + 2O_2$	=	$CO_2 + 2H_2O + Q$
8.	Ethylene	$2CH_4 + 3O_2$	=	$2CO_2 + 2H_2O + Q$
9.	Acetylene	$2C_2H_2 + 5O_2$	=	$4CO_2 + 2H_2O + Q$

Role of oxygen and nitrogen from air:

Theoretically it is easy to assume that sufficient oxygen is present for combination with combustible and that the temperature required to bring about the chemical reactions of combustion can be attained.

However even with proper temperature conditions the most important and difficult problem in the burning of all fuels is the manner of the physical introduction of oxygen to the combustible substances to effect complete oxidation and at the same time to assure the utilization of all or a maximum proportion of the oxygen supplied. Usually in the generation of heat the oxygen required for combustion is supplied by using air and other constituents of the air are nitrogen and small amount of CO, water vapour, argon and other inert gas. Generally in air percentage of oxygen is 23.15% by Wt and percentage of nitrogen is 76.85% by Wt rest are negligible in Wt. Oxygen with its strong affinity for the combustible constituents of the fuel under proper conditions of temperature is separated from the oxygen and nitrogen mixture i.e air and joins the combustible in chemical combination to form with the nitrogen the product of combustion. The heat liberated by combustion transferred by radiation, convection, and conduction to the heat exchanger apparatus and ultimately on leaving the combustion products carry rest heat to waste The quantity of heat so wasted is directly proportional to the temperature and the amount at exit of the products of combustion.
Hence the air used in modern combustion practice is generally as carefully measured as the fuel and great care is taken to effect a tight sealing to prevent the admission of air except in the zone where it unites with fuel. In case of faulty design of coal burner and air register the inert gas nitrogen reacts with excess oxygen in presence of red hot body and forms nitrogen dioxide and further to reacts with oxygen and forms nitrogen trioxide. This nitrogen trioxide mixed with moisture and converted to nitric acid which is very harmful to equipment and atmosphere.

Ignition Temperature:

Every combustible substance has a minimum ignition temperature which must be attained or exceeded in the presence oxygen if combustion is to ensure under given conditions .The ignition temperature may be defined as the temperature at which more heat is generated by reaction that is lost to the surrounding and combustion thus becomes self sustaining. Ignition Temperature depends to a considerable extent upon the surrounding conditions such pressure (generally lower as pressure is increasing). The ignition temperature of combustible substances varies greatly as indicated bellow :

Sl. No	Combustible	Formulae	Ignition Temp.(^{0}F)	Sl. No	Combustible	Formulae	Ignition Temp.(^{0}F)
1.	Sulfur	S	470	5.	Acetylene	C_2H_2	580
2.	Charcoal	C	650	6.	Ethane	C_2H_4	900
3.	Fixed Carbon (Bituminus Coal)	C	765	7.	Hydrogen	H	1065
4.	Fixed Carbon (semi Bituminus Coal)	C	870	8.	Carbon monoxide	CO	1130

The ignition temperature of the gases of a coal varies considerably and is appreciably higher than the temperature of the fixed carbon of the coal. However the ignition temperature of coal may be considered as the ignition temperature of its fixed carbon content.

Oxygen required for combustion and purpose of combustion calculation:

From the reaction table it is evident that one molecule of carbon combines with one molecule of oxygen to form one molecule of CO. Using molecular Wt this reaction is represented by 12 + 32 = 44 i.e. when burning carbon to Carbon-dioxide 12 parts by Wt of carbon combine with 32 parts by Wt of oxygen to form 44 parts by Wt of carbon-dioxide. Now the purpose of combustion calculation is to determine 1) The quantities of the constituents involved in the chemistry of combustion. 2) The heat thus released. 3) The efficiency of the combustion process under ideal practical condition.

The results of this calculation are necessary for the determination of heat transfer and performance of heat transfer equipment such as boiler and their related component. The determination of the quantities of the constituents involved in combustion is necessary to establish the size and the performance characteristics of equipments such as fuel pump or coal feeder and fans, ducts for both air and flue gas. The heat input and the losses in burning fuel in air must be determined and segregated by combustion calculations in order to establish the efficiency of heat transfer to the heat exchanger or boiler. Knowing the amount of each of the various losses is particularly helpful for deciding how efficiency may be improved through the possible reduction of certain of the losses. For instance only enough excess air should be supplied completely to burn the fuel, but we are loosing more heat through stack. So a portion of the stack loss is therefore controllable loss and should be held to a minimum by close control of excess air. Another prime factor affecting efficiency and losses is of course temperature particularly the temperature of combustion gases. The theoretical or adiabatic temperature is the maximum gas temperature that can be obtained under certain conditions. With less excess air or higher air preheat temperature the gas temperature will be higher.

If the gas temperature exceeds about 3200^0 F a phenomenon occurs in which the carbon dioxide and HO constituents of flue gas tend to split into their component parts. This process is called gas dissociation. The affect of this reversal in the combustion process is to reduce the heat of combustion and then reduce the heat producing high temperature. However since the furnace exit temperature usually not high enough for this reason combustion process not affected by this phenomenon.

Inherent and avoidable heat losses :

In the combustion of fuel for the commercial generation of heat, there are certain inherent heat losses over which no control is possible as well as other heat losses which are subject to some control. The inherent or unavoidable heat losses are the result of 1) The discharge of the products of combustion at a temperature higher than the temperature of the fuel and 2) The moisture content of the fuel plus the combination of some of the hydrogen with the oxygen in the fuel. The avoidable heat losses or those which can be controlled to some extent by good design and careful operation can be minimized by:

1) Careful control of excess air. 2) Tolerating virtually no unburnt solid combustible matter in ash. 3) Permitting no unburnt gaseous combustibles in the flue gas. 4) A well insulated out side body of boiler can reduce the radiation loss.

Solid fuel burning system. :

The primary function of fuel burning system in the process of steam generation is to provide controlled efficient conversion of the chemical energy of the fuel in to heat energy. For satisfactory boiler operation requires four ingredients 1. Air 2. Fuel 3.Ignition energy and 4. Product of combustion is properly ratioed, directed and sequenced so that the furnace never can contain an explosive mixture. Basically the fire side safe-guard system supervises the flow and processing of fuel, air, ignition energy and the product of combustion. In this chapter discussions are mainly confined to the tangentially fired furnace.

Sub system:

The fuel burning system should function so that the fuel and air input is ignited continuously and immediately upon its entry in to furnace. The total fuel burning system required to do this consists of sub system for 1) Air handling 2) Fuel handling 3) Ignition 4) Combustion product removal 5) Main burners and boiler furnace.

1) Air handling

The sub system should be capable of supplying air to the main burners on a continuous and uninterrupted basis it should be capable of providing air fuel ratio over the enter range of the burning. The total air required for combustion is divided in to primary air and secondary air. The primary air is that portion of the total air which is sent to the coal mill with the help of P.A fan. The air dries the coal in the mill as the coal is getting pulverised, transports the acceptable coal particles to the furnace and supplies oxygen for combustion of volatiles. The secondary air otherwise also known as auxiliary air helps complete combustion.

Primary air handling system :

At Bk.T.P.P we are using hot P.A .fan. This fan is getting hot air through duct from F.D. fan supplied air after air preheater and for controlling P.A.fan's supplied air temperature cold air is mixing with hot air at the suction duct of P.A.fan, this cold air also supplied by F.D. fan through air preheater bypass duct.

Controls:

Factors governing the control of the primary air are :

1) Coal drying requirement. 2) Fuel pipe velocities to ensure that coal particles remain air born.3) Aerodynamic flow pattern with in the mill. 4) Proper air fuel ratio.

The optimum air flow characteristics as shown in fig -2 are chosen for control purpose so that the correct air fuel ratio along with non - drifting flow fig -3 is maintained through the pulverised fuel pipes. Since the moisture content of the coal received in the power plant varies controls are to be provided for adjusting the air temperature at the inlet mill so as to get an optimum air fuel mixture temperature. At the out let of mill generally fuel air mixture temperature varies between 60 degree to 80 degree according to boiler load and on the rank of the coal. Dampers are provided in the air ducting so as to achieve the above control.

Secondary air system :

The secondary air which is handled by the F.D. fan and this air passes through the tubular or regenerative air heater and to the wind box connecting duct which supplies the secondary air to wind boxes.The secondary air is divided in to two parts namely fuel air and auxiliary air. Fuel air is that air which immediately surrounds the fuel nozzles. Since this air provides a covering for the fuel nozzles for this it is also called mantle air . Auxiliary air is admitted through compartments above and bellow the fuel nozzles Fig -4 and Fig -5

Dampers are provided in the wind box compartments so that correct quantities of air to the individual compartments can be modulated to achieve better combustion in the furnace.

In order to ensure safe light off condition the pre-operational purge air flow is at least 30 % of the full load air flow is maintained during the entire warm up period until the unit load has reached a point where the air flow must be increased to accommodate further load increase.

The 30% air flow is maintained in order to ensure an air rich furnace atmosphere with enough excess air for good combustion. After the unit is online the total amount of air flow is a function of the unit load. Proper air flow at a given load depends upon the characteristics of the fuel fired and the amount of excess air required. The function of the wind box compartment dampers are to proportional the amount of secondary air admitted to an elevation of fuel compartments is relationship to that admitted to adjacent elevation of auxiliary air compartments. Wind box compartment damper positioning affects the air distribution as follows. Opening up the fuel air dampers on closing down the auxiliary dampers increases the air flow around the fuel nozzle. Closing down the fuel air dampers or opening the auxiliary air dampers the air flow around the fuel stream will be decreased. The correct proportioning of secondary air between the fuel compartments and auxiliary air compartment depends primarily on the burning characteristics of the fuel .It influences the degree of mixing, the rapidity of combustion and the flame pattern with in the furnace.

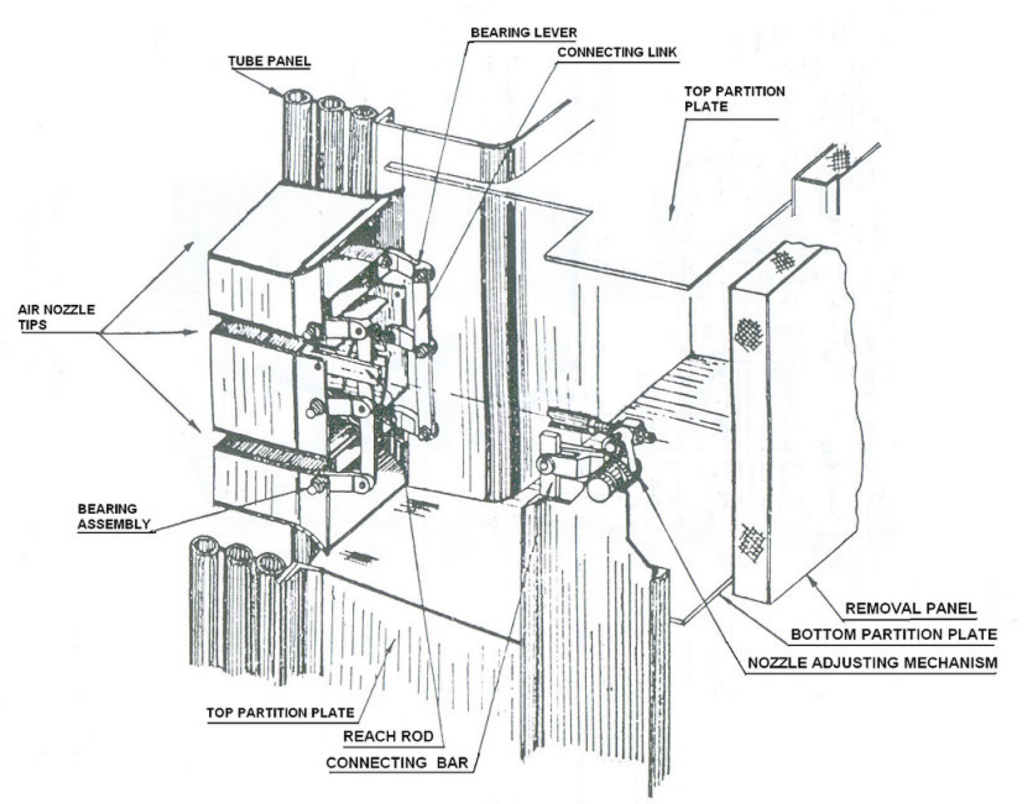


Figure - 5
AUXILIARY AIR COMPARTMENT IN WINDBOX ASSEMBLY - TYPICAL

Fuel air damper controls:

All fuel air dampers are normally closed .They open at a definite time interval after the associated feeders are started. These dampers are to be modulated with reference to the amount of fuel fed to that elevation of fuel nozzles. The fuel air damper opening can be effectively used for the control of flame front position. They are fully opened when both the F.D .fans are off.

Function of Fuel air damper:

More fuel air shifts the flame front further away and makes the flame unstable and consequently hazardous situation develops, Low to medium volatile matter contains coal require least fuel air to be supplied while high volatile coals require larger quantity of fuel air to keep the coal flame away from the nozzle tip at the desired distance. Low fuel air results in burning coal with in the nozzles and hence overheating and deformation of the nozzles and the detoriating of the combustion process, even impingement of flame leading to failure of the boiler tubes and life of the burner nozzle is also considerably reduced.

Auxiliary air damper controls:

During the furnace purge period and initial operation of the unit (up to 30% loading) all elevations of auxiliary dampers modulate to maintain a pre-determined wind box to furnace differential. All these dampers modulated on elevation basis. When the boiler loading exceeds 30% the wind box to furnace differential is changed to a higher value. At this point the auxiliary air dampers which are associated with non operating compartments are closed in time sequence. These dampers controls are done to achieve the wind box to furnace differential as desired.

In general the factors which determine the setting are :

A) Ignition stability. B) Ignition point relative to fuel nozzle. C) Over all combustion condition in furnace. (Fig-7).

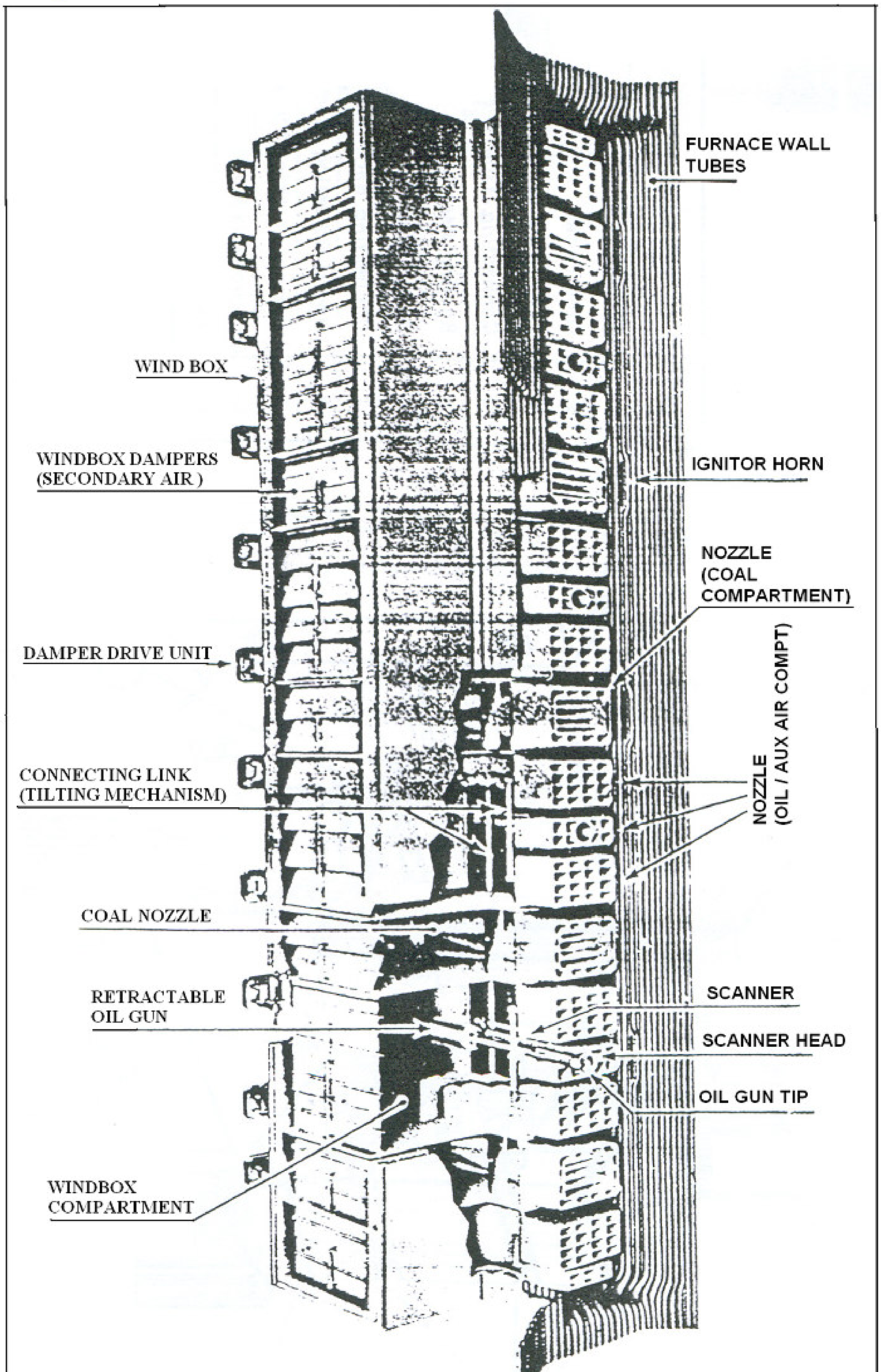


FIGURE - 4
WINDBOX ASSEMBLY- TYPICAL CUT-AWAY VIEW

2) Fuel handling system.:

The principal function of pulverised coal burners are to distribute fuel and air evenly in a furnace. Even distribution of fuel and air means that every square of the cross section of the stream of burning mix in the furnace gets its share of fuel and air and uniformity of distribution is maintained along the full length of the path of the burning mixture through the furnace.

If the distribution is not uniform certain parts of the furnace gets too much fuel and too little air. In the parts of the furnace which gets too much fuel the temperature high and these may be heavy deposit of slag in the furnace. Lack of air in one part of the stream causes incomplete combustion even though over all excess air is maintained at the furnace. It is comparatively easy to get a uniform distribution of coal and air in the furnace which equipped with corner firing . Bends in the fuel pipes may cause uneven distribution of coal across the section of primary air and coal stream for this reason replaceable kicker blocks are provided in the fuel air in let bends so that they will redistribute the air fuel mixture in a uniform pattern before entry to the furnace.

Optimum air coal ratio required for adequate transport characteristics, ignition stability and flame propagation f the air coal stream which is delivered via coal nozzles are chosen during design stage.

Importance is also given to the material selection, lay out of fuel handling system and to easy maintainability of the system components.

Ignition Energy system

The functional requirement of a fuel burning system is to supply an uninterrupted flammable furnace, input and ignite it continuously as fast as it is introduced and immediately upon its appearance in the furnace. Thus no explosive mixture can in the furnace since the furnace input is effectively consumed and rendered inert. Ignition takes place when the flammable furnace in put is heated above the ignition temperature. Supply of correct ignition energy for furnace input is a substantial task. There are many factors which establish the range of combination of ignition energy quality, quantity and location that can provide a satisfactory furnace input ignition rates at any instant.

Major factors deciding the ignition energy requirement:

Six major factors determine the total ignition energy required:

1) Fuel quality, 2) Fuel preparation, 3) Air preparation, 4) Burners' product distribution, 5) Total fuel air ratio, 6) Main burners' flow rate.

Combustion mechanism for liquid fuels:

In the combustion of liquid fuels such as L.D.O (Light diesel oil), H.F.O (Heavy furnace oil) both the ignition and combustion temperatures are higher than the boiling temperature of the individual fuel fraction. For this reason liquid fuel first evaporates from the surface under the effect of supplied heat, then its vapours are mixed with oxygen from air preheated to ignition temperature and starts burning. A stable flame is generally forms at a certain distance from the surface of liquid fuel. The burning rate of liquid fuel droplet is determined by the rate of chemical reaction in the combustion zone, the rate of vaporation from its surface and the rate of oxygen diffusion to the zone. The heat exchange between a droplet and surround medium increases as the size of the fuel droplet increases. It turns out that the evaporation time of a droplet is proportional to the square of its initial diameter. As the rate of combustion is increase with increase of evaporation rate so atomization of liquid fuel is necessary for increase the rate of combustion.

Purpose of liquid fuel burners: For ignition pulverised coal and stabilisation of coal flame at low load and cold start up of boiler.

Table-1

Description	**SUBSTANCE**					**Paraffin Series**		**Misc. gases**	
	Carbon	**Hydroge n**	**Oxygen**	**Nitrogen**	**Carbon monoxide**	**Methane**	**Ethane**	**Acety lene**	**Amonia**
Formula	**C**	**H**	**O**	**N**	**CO**	**CH_4**	**C_2H_6**	**C_2H_2**	**NH_3**
Mol. wt.	12	2	32	28	28	16	30	26	17

High			14093	61100	-	-	4347	23879	22320	21500	9668
Low			14093	51523	-	-	4347	21520	20432	20776	8001
O			1	0.5	-	-	0.5	2	3.5	2.5	0.75
N			3.76	1.88	-	-	1.88	7.53	13.18	9.41	2.82
Air			4.76	2.38	-	-	2.38	9.53	16.68	11.91	3.57
For 100% total air Mole/Mole of comustble reqd. for comustn.	PRODUCTS	CO	1	-	-	-	1	1	2	2	-
		H_2O	-	1	-	-	-	2	3	1	1.5
		N	3.76	1.88	-	-	1.88	7.53	13.18	9.41	3.32
For 100% total air lbs/ lbs of combu-stion	REQUIRED	O	2.66	7.94	-	-	0.57	3.99	3.73	3.07	1.41
		N	8.86	26.41	-	-	1.9	13.28	12.39	10.22	4.69
		AIR	11.53	34.34	-	-	2.47	17.27	16.12	13.3	6.1
	FLUE	CO	3.66	-	-	-	1.57	2.74	2.93	3.38	-
		H_2O	-	8.94	-	-	-	2.25	1.8	0.69	1.59
		N_2	8.86	26.4	-	-	1.9	13.28	12.39	10.22	5.51

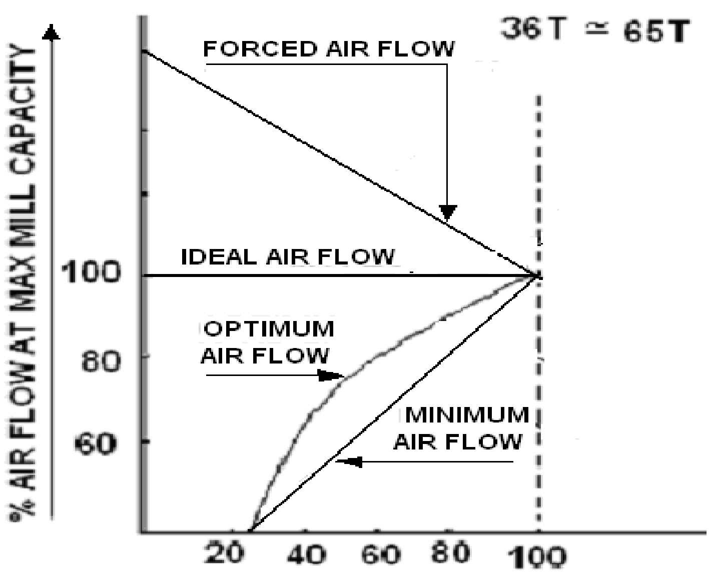
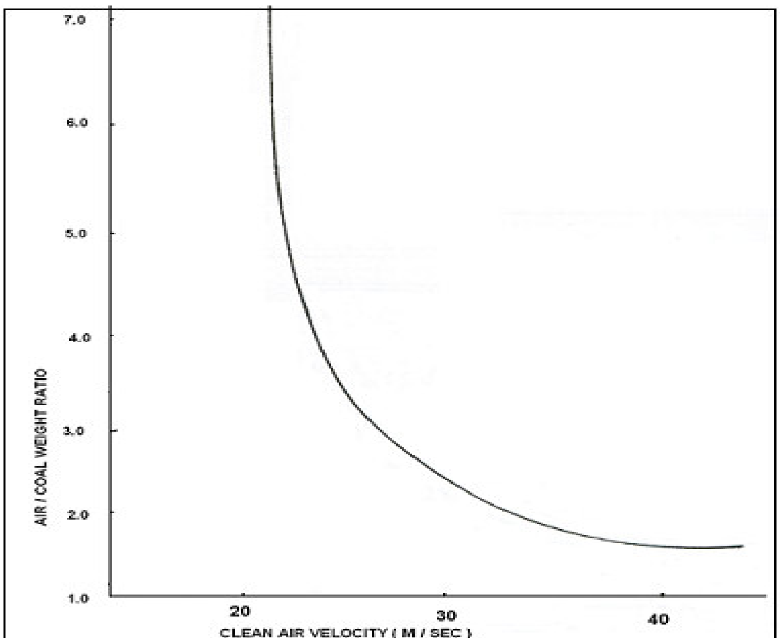


Fig- 2



DRIFTING AS FRICTION FACTOR IN 300 MM COAL PIPE

Fig-3

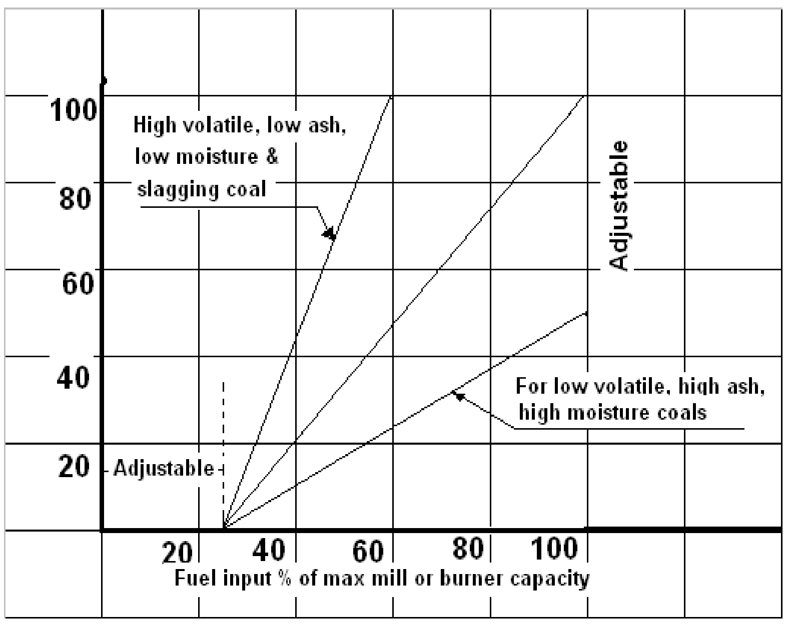


FIG-6

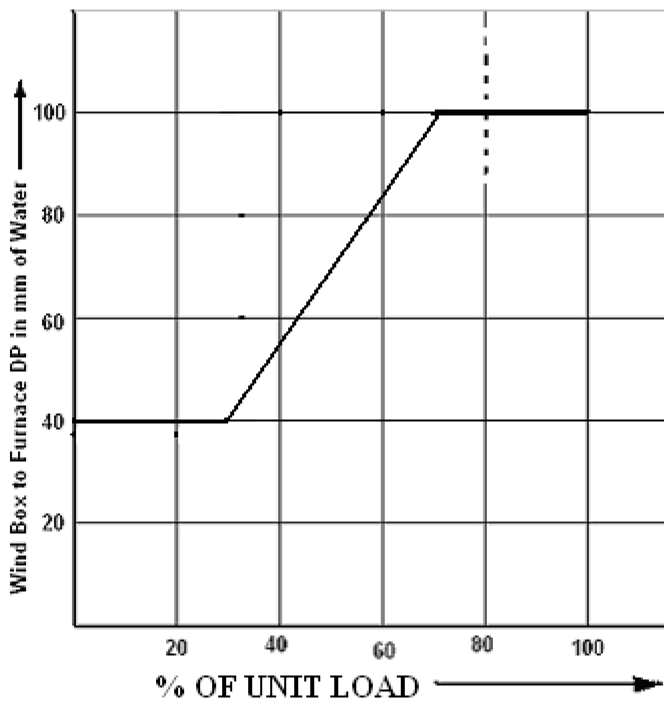


Fig- 7

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SALIENT FEATURES OF MILLING PLANT, TYPES, & SELECTION OF MILLS, CONSTRUCTION DETAILS.

COAL PULVERIZER:

Because of economic advantages of pulverized coal over hard & stoker firing due to high thermal efficiency, reduction in labour cost, & flexibility in operation, there has been a progressive increase in its use for power generation in public utility & industrial plants, & for process steam generation. Pulverized coal is now the outstanding fuel in electric utility & industrial power generation. It has made possible, in no small degree, the development of large steam generating units, & the improvement of the steam cycle. With modern equipment, it is possible to run efficiently, dependably, successfully & safely, almost any kind of coal, pulverized can be burned & controlled as effectively as gas.

Types of pulverizers:

In modern equipment, classification of fineness with simultaneous drying within the grinding zone is a comparatively recent & one of the outstanding developments in the preparation of pulverized coal for steam generation & process heating. While there are numerous modifications the principal types of pulverizers commonly commonly used may be classified as following:

High speed : Impact Pulverizer

Slow speed : Tube mill pulverizer

Medium speed : Roll & race pulverizer – BOWL Mill

Ball & race pulverizer

Selection of Pulverizer: Depends on

The power input required per tonne of coal milled

HGI of coal

Reliability of mill mainly because of failures of bearings & gearboxes.

Easy maintenance

Minimum down time.

Bowl Mill:

A rotating Bowl equipped with a replaceable grinding rings, two or more taper roll, in stationary journals, an automatically controlled feeder a classifier & main drive are the principal components of the bowl mill. In bowl mill the rolls are held in the desired position relative to the grinding ring by mechanical springs, & the centrifugal & force acts only to feed coal between race & the rolls. This mill is suitable for the direct-firing system since the roller journals can be lubricated & the rolls can be adjusted with out shutting down. The fineness of the coal is externally controlled by adjusting the entrance vanes in a classifier as well as by controlling the pressure of the rolls on the material by adjusting the compression springs.

Hot primary air is fed into the mill air scroll, which feeds a shovel port ring. These passages surround the lower part of the mill air is fed from their into the body of the mill via number of angled cones which control the direction of air flow. The high velocity hot air carries the finely ground coal from the outside of the mill table up to the blades of classifier; the classifier separate the heavier particles & returns them to the mill table for further grinding.

Among various designs of pulverizers of the medium family the bowl mill design has a specific characteristic feature in that, there is no metal contact between the grinding element. This is one of the features, which contributes to lesser metal loss on the grinding element.

BALL AND RACE MILL

The Babcock “E” type mill is a vertical spindle; air swept, twin ring & ball pulverizer with the balls rotating Horizontally. Each mill has 10 grinding balls.
There is a single raw coal feed chute & two pulverized fuel out let pipes Grinding force is applied by pneumatic ram forcing the stationary top ring down into the balls & rotating bottom ring.
A mill gearbox is mounted below the mill, driving the bottom-grinding ring via the yoke.

Pulverizing Process:
Raw coal is fed by chute through the top of the mill casing into the centre of the grinding zone centrifugal force carries the coal out wards & through the grinding elements where it is pulverized to a fine powder.

Hot primary air is introduced to the mill through ducts beneath the yoke & thence at high velocity through an annular throat gap giving slightly rearward motion to the air stream between the grinding rings & the mill casing. As the throat gap is rotating the slight blade inclination produces a near vertical air flow. The pulverized coal emerging from the grinding zone is entrained in the air stream & carried upwards inside the mill. Some of the larger particles fall back into the grinding zone to be reground.

The mixture of pulverized fuel & air passes up through the static classifier where the coarse zone for further pulverizing. The fine particles of fuel are carried upwards in the air stream & leave the classifier through the product outlets & away to the burners.

CONSTRUCTION DETAILS:
The main structure of the mill is fabricated from mild steel in three cylindrical sections:

Mill housing support:
A bottom section support assembly, provides the support for the mill & incorporates the gear box base plate, top plate, seal air pipe work & air seal ring, yoke coupling guard & rejects hopper. Rails in the gearbox base

plate are in alignment with exterior rails outside the mill & provide a track, along which the gearbox withdrawal trolley moves.

A sealing air supply, introduced beneath the mill yoke, prevents the escape of pulverized coal through the mill drive mechanism.

The reject hopper (pyrities box) is positioned on the side of the mill so that the ploughs push around ungrindable material rejected from the grinding zone until it falls into the rejects hopper. The rejects hopper has on inlet gate valve, which is first closed. The front of the rejects hopper has an air tight sealed door, which in then opened for the removal of the rejected material by hand. The front door is closed & resealed & the I/L gate valve is opened.

Mill housing:

A centre section that is fabricated from steel plate with chrome carbide clad liner plates attached inside to minimize wear.

The mill housing incorporates the spider guide housing wear plates & throat plate. Primary air inlets are provided in the mill housing, with bolted access plates. Access to the ploughs under the yoke in by means of bolted doors situated around lower half of the mill housing.

It contains the rotary grinding elements that comprise ten hollow cast alloy steel balls, which run between two troughs shaped grinding rings. The lower grinding ring is keyed to a yoke, which is driven by the mill motor via a right angle drive gearbox. The lower ring rotates horizontally at approximately 34rpm. The upper ring is prevented from rotating & has a certain amount of vertical movement so that load can be applied to the grinding balls & lower grinding ring via the mill loading sys. Both upper & lower rings are manufactured from special wear resistant Hi – Chrome white CI & the balls are manufactured from 3.5% chrome alloy steel

The upper ring is keyed to a steel spider, which is located by guides in the mill centre section. Both spider & upper grinding ring have a certain amount of vertical free movement.

The spider guide assembly restricts rotary movement, whilst the spider 4 spindle arms assemblies allow vertical movement of a spider & top-grinding ring to take up grinding rings & ball diameters wear. Just inboard of the four spindle arm assemblies are the loading arm cups that transmit grinding pr. From the vertically operating hydraulic sealed – pneumatic loading cylinders via the spider to the grinding element.

A ball access door is positioned in the mill housing & when opened provides a large opening into the mill, through which grinding balls can be passed. Having a ball access door means it is no longer necessary to remove the top of the mill when changing grinding balls.

Classifier housing:

A top section accommodates the loading cylinders for the mill loading gear. A platform around the top section provides access to an inspection door & to the top of the mill for routine maintenance & is served by a ladder.

The upper section of the mill comprises the classifier assembly & two outlet turrets. The classifier assembly is fabricated from steel plate & consists of a large inverted multi – angle cone & central cylindrical raw coal inlet chute inside a cylindrical housing mounted on the top of the mill housing. The cone is suspended from the top of the classifier housing by support rod attached to the larger end of the cone.

The classifier blade arrangement comprises 16 swiveling vertical axle blades fixed & spaced equi-distant around the upper end of the classifier cone. The angle of the classifier blades can be varied by adjustment of the blade spindles which extent through the top of the classifier housing.

Adjustment of the blade angle provides a degree of regulation to the fineness of the pulverized coal particles passing out of the mill.

An integral part of the classifier housing is the 4 points support steel work for the mill loading system. Each point locates two pneumatic/ hydraulic loading rams, which transmit pressure to the grinding elements.

The thermocouples signals are used for mill control as well as fire detection.
Four connections are provided, on the mill casing for inerting steam supplies.

The function of pneumatic loading cylinders is to provide a constant grinding pressure to the upper ring & to compensate automatically for ball & ring wear. Grinding pressure is applied via 8 cylinder rams, which are mounted in pairs equally spaced around the mill. N_2 gas is used as the ram actuating medium & the pressure is maintained by a control system mounted in a cabinet adjacent to the mill.

Special Oil (Shell OMALA 100) is used in the cylinders as a gas seal & as a lubricant, its pressure being similarly maintained by the control system. There is differential pressure between the oil & N_2 gas with oil pressure being higher than the gas pressure, a gas/oil pressure intensifier maintains the pressure differential. Each mill has a separate supply ring main pipe work for N_2 gas & oil connected to each cylinder in parallel with the control cabinet. For monitoring purposes there are pressure switches for alarms & pressure gauges.

The gearbox, through an intermediate shaft, provides a double reduction unit by spiral bevel gears at the input end & helical gears to the output shaft.

A pressurized lubricating oil system supplies both the mating gear falls & bearings with lubricating oil. The lubricating system comprises and electric driven oil pumps, filters, oil flow indicator, pressure switch & temperature indicator. The lubricating oil has a cooling water supply to remove heat from the oil that has been picked up in the gearbox.

Mill Maintenance:

Regular routine maintenance is both necessary & economic. Its aim is to maintain the system in an efficient working state by regular checks & routine attention to components. The following checklists should be regarded are guide to assist Engineers/Maintenance staff in carrying out scheduled examination.

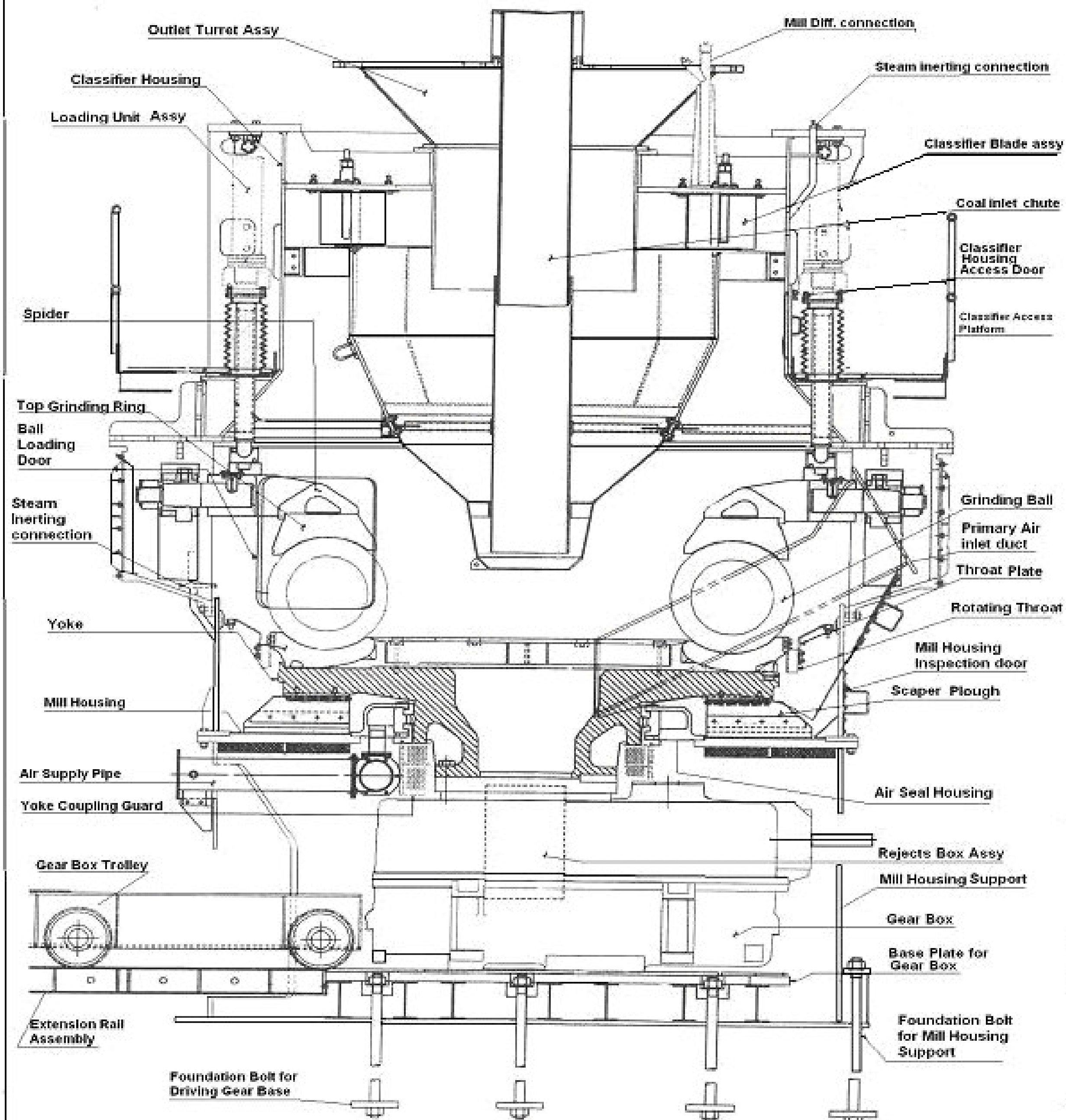
Check List	**Daily**	**Weekly**	**Monthly**	**6 Months**	**External**	**Internal**
Visually checks for leaks from Mill housing & couplings.	√				√	
Visually check mill loading pressure & seal oil level	√				√	
Visually check sight glass in loading cabinet for loading system.	√				√	
Check gearbox lubricating oil system pressure & temp.	√				√	
Check mill reject hopper contents	√				√	
Check Gear Box oil level using a dipstick & top – up if necessary		√			√	
Check Gear Box oil filter differential & clean as necessary		√			√	
Check Grinding elements & ball Sizes & record result.			√			√
Check internal state of mill housing for erosion.			√			√

Measure & record spider guide wear plate gaps.				√		√
Plough blades under yoke are functioning correctly & properly fixed to it. Replace if necessary			√			√
Check classifier cone for wear & blades for erosion, looseness & correct angle & record				√		√
Check reject gate & door seals are in good condition				√	√	
Check gear box holding down bolts & re torque as required				√	√	
Alignment re grease of coupling between motor & gearbox.				√	√	

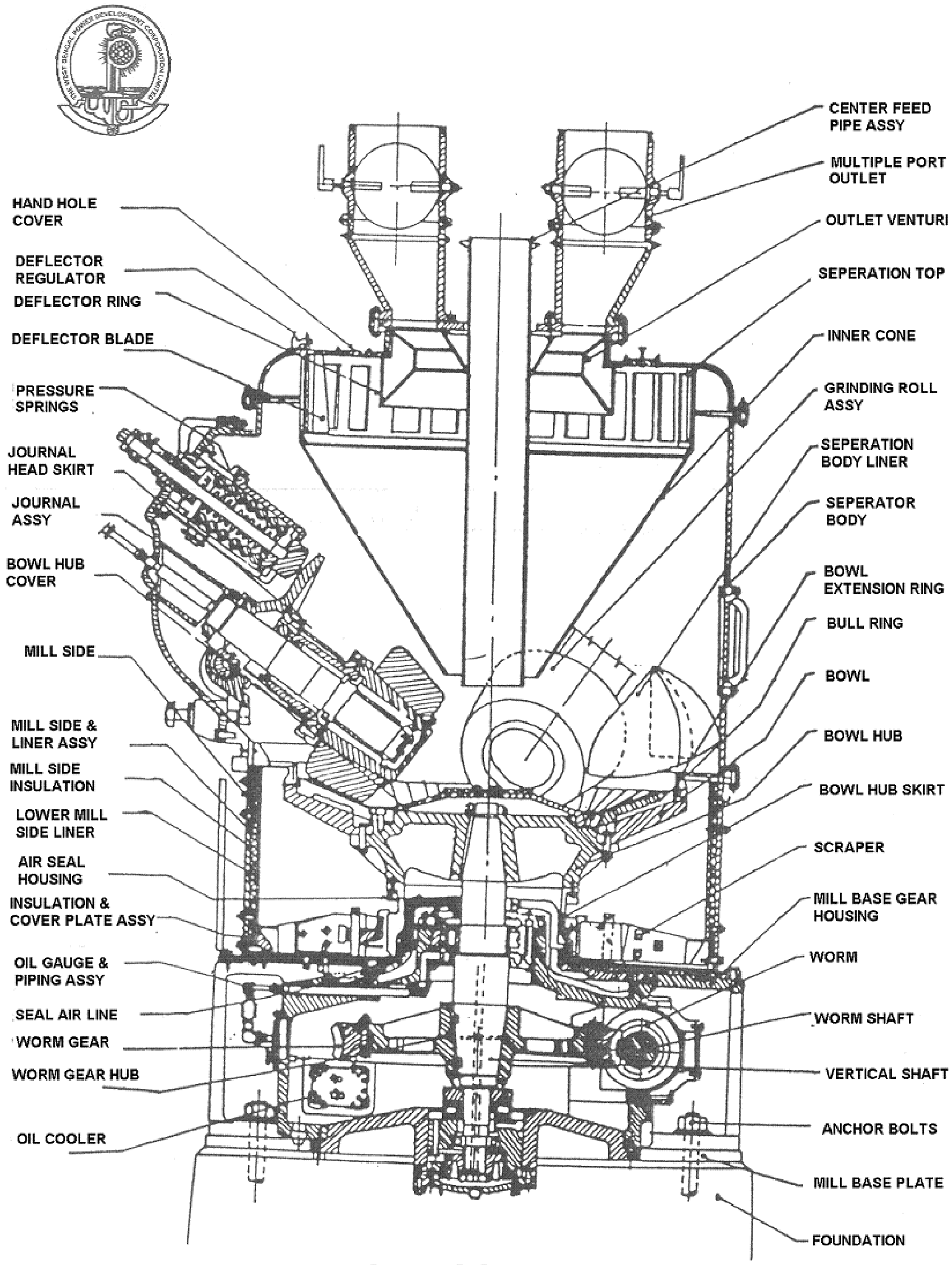
Addition of ball filling can be done by comparing pulverizing mill ball diameter is with in "fill-in ball" dia (only + 5mm difference accepted). Fill-in-Ball diameter 699mm.

Cares should be taken during changing of Rings & Balls

Classifier and Turret: Condition of Turret Internal Liners Condition of Classifier Spindles and Bearings Classifier Blade Settings Wear of Blades Condition of Coal Chutes	**Loading Cylinders:** Condition of Bellows Condition of Cylinder Top Support Brackets Condition of push rod
Spider Guide Assembly: Spider Box Wear Plates Spider Arm Wear Plates Gap Between Wear Plates (DE & NDE ends) Wear Plate Holding Screws	**Spider & Top Grinding Ring** Top Grinding Ring Ref. No. Gap Between Spider & TGR Gap Between Spider Key & Ring Key Way (NDE) TGR Depth
Ball: Diameter of Grinding Balls Outside Surface of Condition of Grinding Balls	**Lower Grinding Ring & Yoke:** LGR Ref. No. LGR Depth Gap Between LGR Landing Face and Yoke Gap Between Key and Keyway (NDE)
Rotating Throat: Condition of Rotating Throat Condition of Fixed Throat Gap Between Rotating and Fixed Throat	**Air Seal Rings:** Gap Between Yoke Stem and Air Seal Ring Condition of Seals



Arrangement of 10E Pulveriser



BOWL COAL MILL

27

DESUPERHEATERS

Though superheaters are designed in such a way that the heat absorbed by radiant and convection superheaters always try to maintain the steam temperature constant during variation of load, but in practice the necessary control is achieved by using desuperheaters.

De-superheater are provided in the superheater connecting links and the cold reheater lines to permit reduction of steam temperature when necessary and to maintain the temperature at design values within limit.

Temperature reduction is accomplished by injecting spray water into the path of the steam, through a nozzle at the entering end of the de-superheater. The spray water source is form the boiler feed water system. It is essential that the spray water be chemically pure and free of suspended and dissolved solids, containing approved volatile organic treatment material in order to prevent chemical deposition in the superheater and reheater and carry over of solids to the turbine. The location of the desuperheaters helps to ensure against water carry over to the turbine and also eliminates the necessity for high temp. resisting materials in the desuperheater construction.

Spray type de-superheaters are installed in the connecting links between the LTSH and the platen inlet header (for Stage –I) and between platen outlet header and final superheater inlet header(for Stage –II)

At Reheater :- Two stray type desuper heaters are installed in the cold reheat line leading to the inlet header.

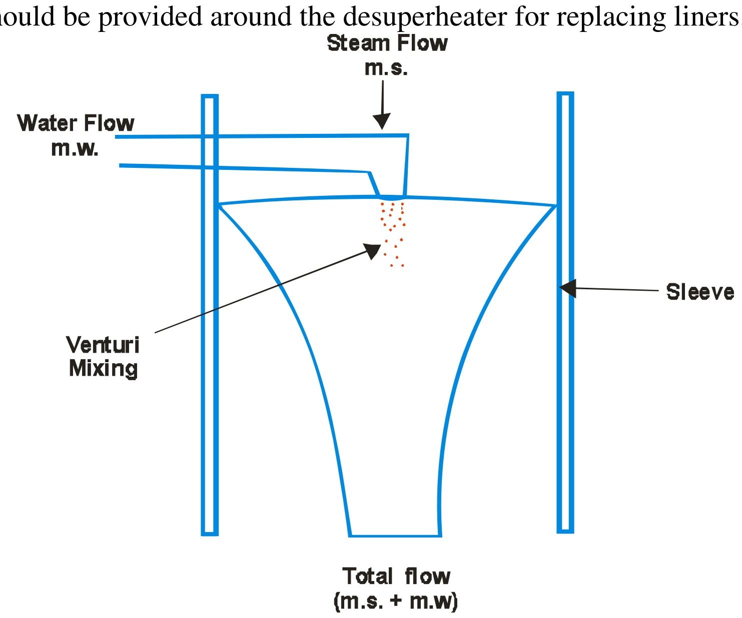
Control Station :

A control, V/V linked to an automatic control system regulates the flow of spray water supplied to each desuperheater, manually operated V/Vs are also installed on both side of each control V/V to permit isolation when required. A regulating V/V in the by pass line around each automatic control V/V and the two isolating V/Vs should be used only in the event of an emergency or when an automatic control V/V may require maintenance.

A Block V/V is installed in the supply lines to the reheat desuperheater control station as an additional shut off value. This Block V/V must be interlocked to close upon a turbine trip, closing the block V/V will prevent water from entering the turbine through the cold reheat piping in the event of the spray water control V/V should leak.

Maintenance :

Each desuperheater is fitted with a renewable liner to take the wear of erosion from the spray water Streams, these protecting the main desuperheater shell. Excessive noise from within a desuperheater usually indicates worn liner and the service dept. should be contacted when this or any such abnormal condition may arise. Sufficient clearance should be provided around the desuperheater for replacing liners.



The spray nozzle injects water into the throat of a mixing venturi, where the water mixes with high velo. Steam into the throat, vaporizes and cool the steam. The venturi, & a thermal sleeve (a high cr. Steel) protects the main steam pipe from thermal shock caused by any unvaporised water droplets that otherwise might impact on the pipe. The water used for spray will be of high purity so that no deposits (scale) are added on the superheater tubes, Pipes and turbine blades.

The spray type desuperheater or attemperator has quite satisfactory in its service. It provides a rapid and sensitive means for temp. control. It the desuperheater is located after the last stage superheater the steam temp. exceeds the max, desired temp, before attemperation which is harmful. The control is done one stage ahead and it is preferred practice.

<u>BLOW OFF VALVES</u>

There must have two slow opening valves or one slow opening and one quick opening valves. The Blow-down connection to the Boiler must be at the lowest point of the Boiler so as to drain it properly.

A slow opening type of valves is one which requiring at least five 360°C turns of the operating mechanism to change from full closed to full-opening and vice-versa.

Why blow downs are necessary on Boiler?

Blowing down does the three jobs :

Rapidly lowers the Boiler –water level in case it accidentally rises too high. This action reduces the water carry over with the steam.

Permits removal of precipitate sediments or sludge while the Boiler is in service , otherwise, it might be necessary to take the Boilers off to wash out sludge accumulation frequently.

Controls the concentration of suspended solids in the Boiler . The solids would settle on metal parts , reducing heat transfer and causing metal overheating where the scale is located and rupturing the tubes.

Three Blow down drains –

CBD drain (continuous blow down))
IBD drain (Intermittent Blow down)
EBD drain (Emergency Blow down)

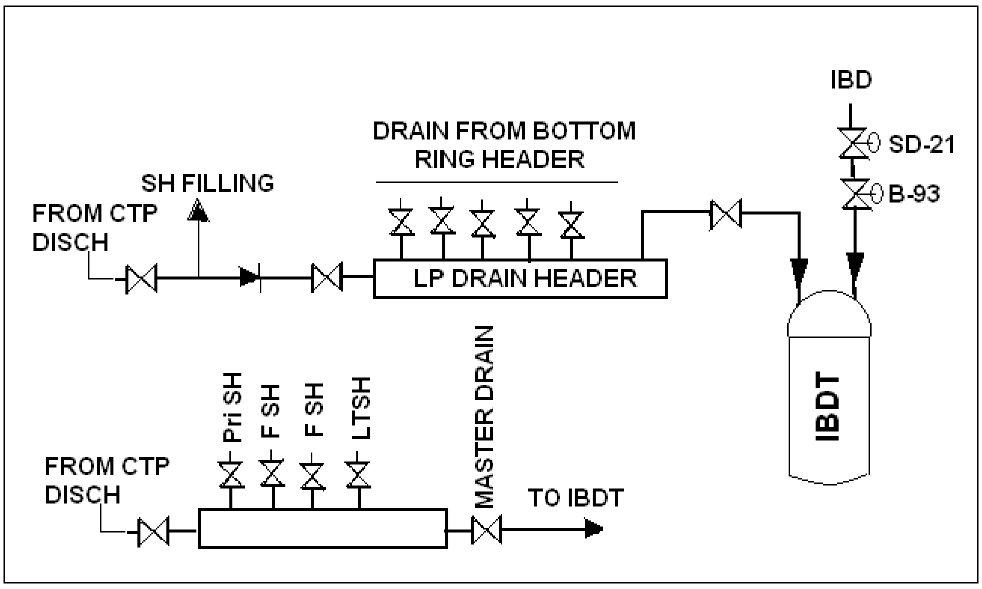
To put CBD tank into service v/v A must be closed , and CBD tank controller LCV01 should be put into Auto after proper line up of the same.

1. CBD drain (continuous blow down))
2. IBD drain (Intermittent Blow down)
3. EBD drain (Emergency Blow down)

To put CBD tank into service :-

1. Open isolating valves of main CBD control valve .
2. Close CBD control valve .
3. Open CBD tank atmospheric vent v/v.
4. Check CBD tank safety valve is in service
5. Open CBD tank to deaerator valve.

Now open the level control valve and put it ‘Auto’ for auto mode operation.



2 nos. – FSH drain
1 no. – Platen S/H drain
1 no. – Primary S/H drain.

Boiler filling - Initial Blr. Filling done through one bottom ring header DRN & ECO drain (see at LP DRN HDR) by opening DM -36 from CTP disch. When all drum vents and HP drains are kept opens.

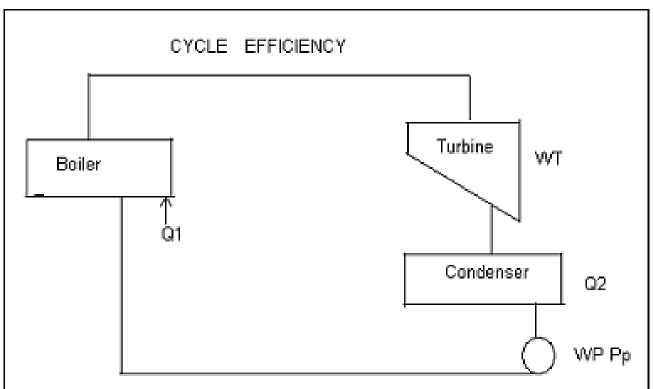


FIG.1 FLOW DIAGRAM OF RANKINE CYCLE

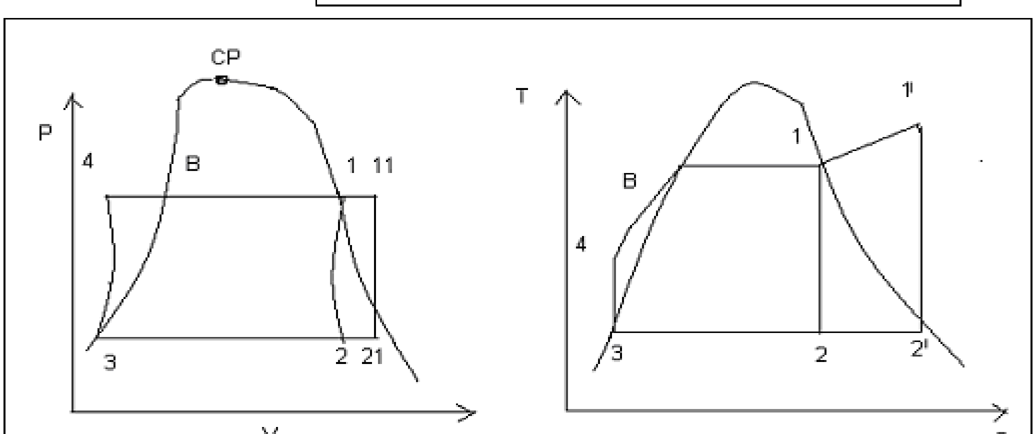


Fig.2 Ideal Rankine cycle P-V diagram

Fig. 3 Ideal Rankine cycle T-S diagram

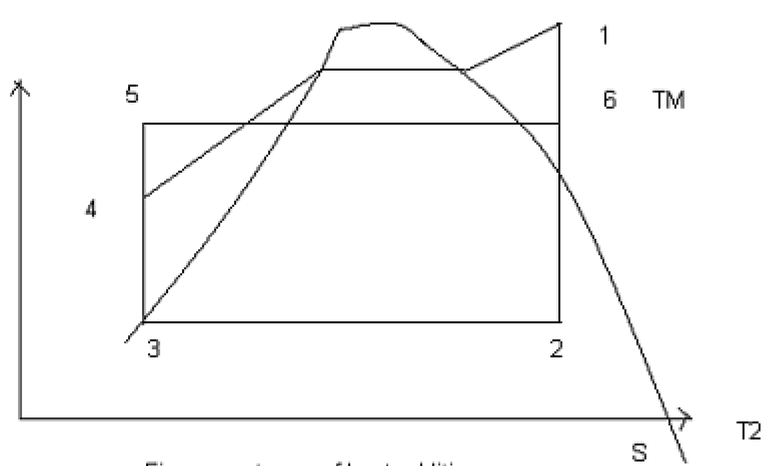


Fig. mean temp. of heat addition

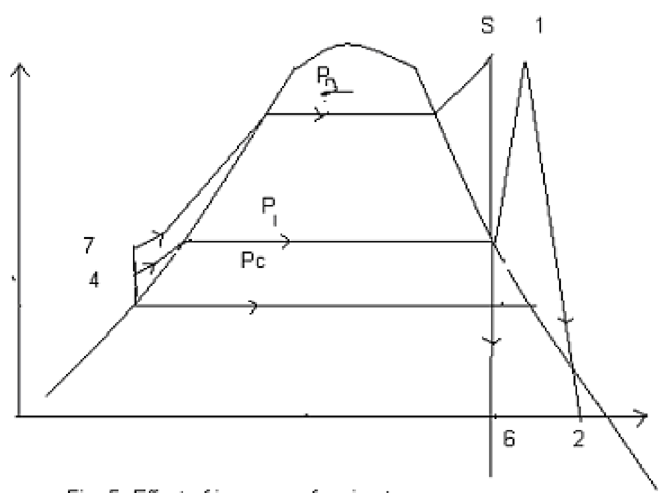


Fig. 5. Effect of increase of main steam pressure

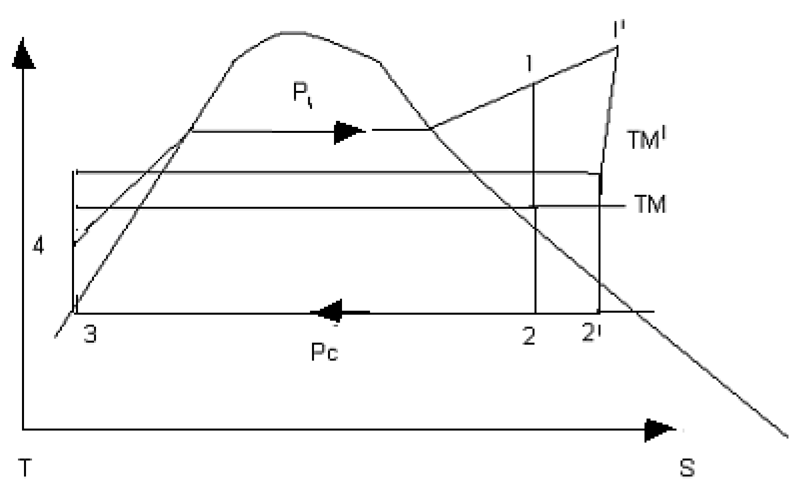
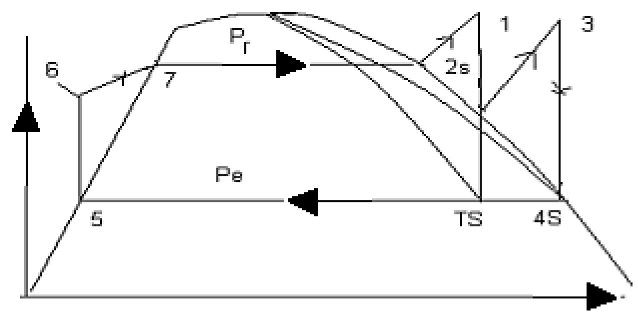
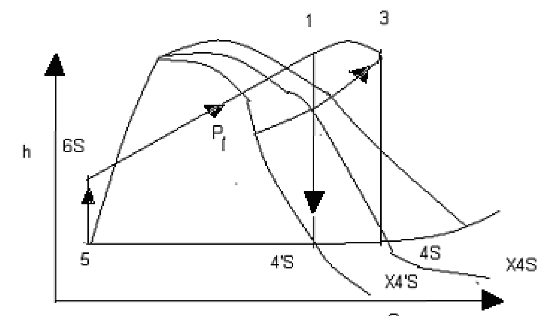


Fig.6 effect of superheat on mean temp. of heat addition.



Effect of re-heat
T-S diagram



Effect of reheat
h-s diagram

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INTRODUCTION TO VALVES, DAMPERS, PUMPS AND SOOT BLOWING SYSTEM USED IN BOILER AREA

VALVE :

Valve is a Boiler Mountings, which is used as a flow control Device.

Principal Purpose of valves used in thermal power plant:

- Shut off or blocking
- Throttling
- Draining or venting
- Relief the excess header pressure

Basic Constructional feature:

Valve body is a cast, forged or machined element, to house valve mechanism. It must be sufficiently strong to resist internal pressure & load from piping & actuator. The closing element is a disc that must fit leak tight against the valve seat. The motion of closing element is controlled from out side by means of either a sliding stem or rotating stem attached to the closing element.

Packing is used to prevent gland leakage, which allows the stem to slide. Considerable pressure is required to open & close large valves. The pressure retaining part of a valve is called bonnet, which guides the stem & contains the component for stem sealing.

Valves are attached to the piping:

- Valves with pipe thread are screwed in to position.
- Valves equipped with flanges are bolted in position
- Valves are also welded into position (HP boiler)

Classification:

According to the direction of flow of fluid valves are classified as:

Gate Valve: It is used in parallel flow. It consists of a gate (disc) that can be raised or lowered into the passageway, which is straight through opening in the body. The gate is right angles to the flow & moves up & down in between slots (Valve seats) that hold it in the correct vertical position.

These valves are used chiefly where they are to be operated either wide open or closed. They are employed in steam & water pipelines of 100 mm to 600 mm dia.

Globe Valve: It is used in perpendicular flow. It is linearly operated valve using a disc like enclosure member who is forced into tapered hole called a seat. The enclosure element is fitted to

the valve stem Globe valves can readily throttle or modulate flow over a long period without serious damage.

Mode of Operation

- Hand Operated
- Motorized Operated
- Pneumatic Operated

Types of corrosion attack a valve:

- Uniform Corrosion
- Pitting Corrosion
- Bimetallic Corrosion
- Selective Corrosion
- Stress Corrosion Cracking.

Control of valve Corrosion:

- Modification of Material
- Modification of Component Structure
- Plating & Surface treatment
- Modification of Environment

Valve Material: Stainless Steel, Alloys, Ceramic Coated etc.

Safety valve:

- It is a device that lets out the excess steam when the steam pressure in the boiler, Steam header or pipeline exceeds the working pressure.
- It works automatically. When the steam pressure exceeds the working pressure, it automatically vents some system pressure returns to the normal working limit.

Types of Safety valves:

- Spring loaded safety valve
- Dead weight safety valve
- Lever safety valve
- In Bk.T.P.P. at boiler side all safety valves are spring-loaded safety valve.

Terminology:

- Set pressure: The pressure at which the valve will open
- Reset pressure: The pressure at which the valve closes.
- Blow Down: $\dfrac{\text{Set pressure} - \text{Reset pressure}}{\text{Set pressure}} \times 100\%$

Simmer: Characterized by the audible passage of a gas or vapor across the seating surface just prior to pop. The difference between this start to open pressure & the set pressure is simmering& is generally expressed as a percentage of set pressure.

Chatter: Chatter is abnormal rapid reciprocating motion of the movable parts of a valve in which the disc does not contact the seat

Damper

Dampers are used for isolation & modulation for control purposes. Al though the mechanical design of the damper is the some weather for isolation or control. Some modulating dampers operate by opening only blades of the multi blade assembly to a certain percentage when low flows are required. Separate actuators are normally required to control these blades, but one actuator working through a differential linkage can also be used.

When a good condition and properly adjusted, dampers will provide reasonable shut off, but damper blade edges & seals deteriorate in service, especially in dusty condition & a gas tight seal after a period of operation cannot be expected.

The blade spindles do not seize in the bearing & also blade linkage is strong enough to take the thrust from the actuator if bearings are stiff from lack of use.

Multi blades dampers are generally used in Primary Air Fan Suction & Discharge Side and also used in F.D. Fan Discharge Side and inlet guide vane of I. D. Fan.

Guillotine Damper:

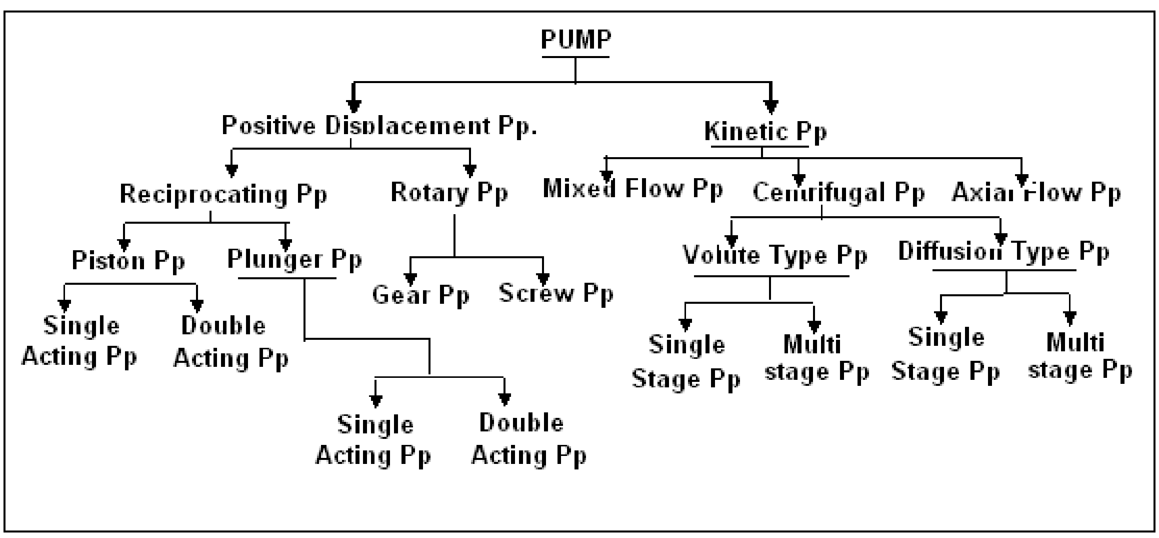
In addition to multi-Blade dampers, Guillotine dampers are available with one sliding blade, which seals into its frame in the duct.
This type of damper can be opened of closed either manually or electrically. This type of damper is use as part of the system employed to isolate the I/L of each precipitant while the boiler is operated at reduced land. Isolation of Primary air system by guillotine damper can be difficult because of the, limited space available for the frame, which holds the guillotine when the damper is open.
Guillotine Dampers are generally used in E.S.P. inlet and outlet side and I. D. Fan discharge side in the flue path area.

Pump

Most of the industrial processes in & out of plants involve transportation of fluids & the pressure is the only Mechanical means available to facilitate this transportation. Work has to be done by a Prime mover i.e. Electric motor, diesel Engine etc. in order to enable the pump to discharge its function, because the pump is incapable of transporting the fluid on its own.
Pump is a mechanical device to increase pressure energy of a liquid.

Classification:

According to mechanical configuration pumps may be classified:



Centrifugal Pump:

Centrifugal pumps are equipped with a volute or casing; collect the liquid discharged by impeller & convert Kinetic energy into pressure energy. In boiler side DMCW pumps, which are volute type, single stage pump are used for bearing cooling and lubricating oil cooling purpose of the equipments.

Reciprocating Pump:

The piston moves up & down in a reciprocating pump. During suction stroke, the pump cylinder fills with fresh liquid & the discharge stroke displaces it through the discharge line. Such pumps develop very high pressure.

All chemical pumps are used in boiler side are reciprocating piston type single acting pumps.

Gear Pump:

The gear pump, which consists of two gears, is a rotating machine, yet its action on liquid to be pumped is not dynamic & it merely displaces the liquid from one side to other.
On the suction side, the liquid fills up the gaps between the meshing gears from the direction, opposite to that of rotation. The liquid then after passing around the casing, finds its way to pressure side when the gears rotate.
For pressure control and flow control spring adjusted relief valves are provided for the pressure and flow in pump increases beyond desired value. In boiler area gear pumps are used for cooling of the bearing and gear teeth of Coal Mill by supplying lubricating oil.

Screw Pump:

A motor drives helical screw mounted on one shaft & the other shaft is merely coupled to the first shaft. Both spindles are enclosed in a casing. The passages of spindles mesh with and another allowing small play. Each spindle is provided with a portion of right hand screw & left hand screw, hence the pump is double flow pump in which suction takes place in axial division from sides & is carried to centre of pump.
For pressure control, a spring adjusted relief valve is provided which opens when the pressure in pump casing increases beyond desired value. In boiler area screw pumps are used for supplying of lubricating oil to the bearings of ID Fans, FD Fans, PA Fans and also used for supplying LDO, HFO.

Diagnosis of Pump troubles:

Pump operating trouble may be either hydraulic or mechanical. In the first category, a pump may fail to deliver liquid, it may deliver an insufficient capacity or develop insufficient pressure or it may lose its prime after starting.

Centrifugal Pump:

***A. Hydraulic trouble due to*:**

i. Pump not primed. ii Pump or suction pipe not completely filled with liquid.
iii. Suction lift to high iv. Excessive amount of air or gas in liquid

B. Mechanical trouble due to:

i. Foreign material in impeller ii. Misalignment
iii. Foundation not rigid iv. Shaft bent
v. Rotating part rubbing on stationary part vi. Bearing whorl
vii. Impeller damaged viii. Lack of lubrication

Rotary Pump:

A Hydraulic trouble due to:
i. Pump not properly primed ii. Suction pump not submerged
iii. Strainer Clogged. iv. Suction lift too high
v. Air leaking in suction

B. Mechanical trouble due to :
i. Drive shaft bent ii. Misalignment
iii. Corrosion iv. Relief valve improperly sealed

Reciprocating Pump:

A. Hydraulic trouble due to:
i. Insufficient suction pressure ii. Partial lose of prime
iii. Cavitations

B. Mechanical trouble due to :
i. Main bearings loose ii. Packing worn
iii. Proper lubrication / oil level low iv. Plunger loose

Terminology:

Priming
Cavitation
Net Positive Suction Head

SOOT BLOWING SYSTEM:

Soot:

Product of fuel combustion inside boiler in the combustion zone mainly ash generally stay at molten state, which usually sticks to boiler tube surfaces which become sticky. Repeated action of this phenomenon develops a layer over the tubes. This sticky layer is called soot, which ultimately reduces the heat transfer and effect of that starts corrosion of the tubes and thus finally leads to tube rupture. The temperature of super heater zones should be kept below the ash fusion temperature (ash fusion temperature is >1400 ^{O} C) approximately 1150°C to avoid formation of soot.
As such removing action i.e. "Soot Blowing" is carried out as well as to restore longer life of the tube.

Soot Blower:

Soot Blowers are provided to remove combustion deposits from the boiler surface to ensure effective heat transfer to the steam. Generally two types of medium used during soot blowing.

Choice of Soot Blowing Medium:

i. Steam: Capital cost of steam pressure reducing equipment & drains is less than the cost of compressors, motors, and controls for air system.
ii. Air: Effective soot blowing is available at any boiler load & particularly on start up & Shut down with oil-fired boilers and not necessary drain & pipe work of condensate.
In boiler at Bk. T.P.P. steam is used as a soot-blowing medium.

Normally superheated steam is used. The steam tapping is taken from super heater header (SHH – 10). The enthalpy of superheated steam is selected such that after steam pressure is reduced to the blowing pressure, the steam will have enough superheated & also will be below 427^{o}C. This limitation is to avoid the use of alloy steel piping.
About 50^{o}C superheat is preferred to prevent the water particle being blown through the nozzle, which may lead to tube cutting & consequent tube failures. The steam pressure reduced during soot blowing to 18 – 22 ksc.

Types of Soot blower:

Long Retractable Soot Blower (LRSB):

LRSB is a boiler-cleaning device in which a rotating lance extends into & retracts from the blower to make sure that the cleaning medium – Steam – directed through the nozzles removes the deposits from tube or wall surfaces.

The lance is attached to a traveling carriage, which runs on tracks inside the blower housing. The carriage & lance are moved by means of a traversing chain operated by a 0.37 KW electric Power pack. Rotary motion is applied to the lance through the traveling carriage by a second chain driven by a separate 0.45 KW electric power pack. Control of movement is by a stop limit switch & a reverse limit switch.

Standard traversing speeds are available in various increments from 1.6 to 3.25 m/min. standard rotating speeds are available in various increments from 3.25 rpm to 10 rpm. These are used to clean soot in Super heaters, Re heaters, Economizer Coils of boiler.

No. of LRSB: 30

ii. Wall deslagger :

The deslagger consists of a stationary body & rack gear housing & a rotary gearbox assembly to which the swivel any is attached. Bushing at each end of the body casing supports the swivel tube assembly. The horizontal guide rod is used to assure proper alignment of the rotary gear assembly.A stationary electric motor is situated on the right side of the blower. This motor, through a Rack gear housing Assy. Operates a pinion which drives a horizontal rack assembly, the outer end of which is fastened to the rotary gearbox Assy.When the Rotary gearbox approaches the fully extended position a ramp cam attached to the free end of the rack contacts a bearing surface, which is a part of the clevis bracket assembly and pushes the valve stem assembly, admitting the steam to the swivel tube. When the blower is started the rack pinion moves the rack and rotary gearbox towards the boiler. Operation of the Rack gear housing causes rotation of a shaft extending out from the rack gear housing into a switch box. Located in this switch box are two cam actuated limit switches. One cam holds limit switch LSTE in the open position when the blower is fully retracted. Extending of the blower moves the cam allowing LSTE to close. The blower is then under its own control.

- Wall deslagger used in water wall tube surface of the boiler.
- These are used in water wall of furnace to clean soot.
- No. of Wall blower: 56

Effect of Soot Blowing on Steam generator:

Operation data from 210MW Boiler indicate that approximately 58.8 kg. Per hour/Blower steam required for soot blowing in wall deslagger and 420 kg. Per hour/Blower steam for LRSB, so the net increase in boiler heat input during soot blowing time.

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ASH HANDLING SYSTEM

Ash : Ash is the incombustible parts in coal i.e. residue of combustion. Ash may be of two forms as fixed ash and free ash. Fixed ash present in coal comes from the original vegetable matter and cannot be removed from coal before burning the coal. The free ash comes with the coal in the form of clay, shale, sand and pyrites during handling the coal in mines or in sites. The free ash can be removed or reduced by mechanical processing of coal such as washing or screening. The ash percentage of Indian coal varies from 25% to 50%. The ash contains silica, alumina, Ferric oxide, calcium oxide calcium nitrate, magnesium oxide, magnesium nitrate and alkalis. Silica content of Indian coal is as high as 60 to 65%, which causes erosion in ash handling equipments. So, ash-handling equipment should be robust in construction but simple in design.
About 20% of total ash produced in furnace is collected in the water impounded bottom ash hopper placed below furnace and this ash is known as bottom ash. And rest 80% ash is carried out with flue gas known as fly ash.

Clinker : If the furnace temperature goes above the ash fusion temp of ash, then the ash melts and combines with coal particles and ash nearby and forms a lump, which is known as clinker. Clinker is as hard as stones. So, ash fusion temp of coal used must be higher than the maximum furnace temp, otherwise clinker formation will occur. A clinker grinder is used in bottom ash removal system for grinding ash during ash removal process.

Function of Ash Handling Plant: The function of an ash handling plant is:

i) To collect and store ash produced in furnace in different hoppers smoothly and efficiently.
ii) To convey the collected ash from different hoppers without any nuisance to a storage.
iii) To dispose the ash smoothly from storage.

Ash Utilization:

i. For producing cement (this type of cement is known as Portland pozolonic cement), asbestos firebricks.
ii. For filling low land, deserted mines etc, for road embankment.
iii. For treating acidic soil. Ash adjusts the pH to optimum levels for plant growth. Ash also supplies sulpher, boron, calcium, and zinc etc essential nutrient to soil. It is also found that if ash is used in limited quantity in soil, it increases the yield of corn, turnip, white clover and asfalla.
iv. Metals like At, Fe, Si and Titanium can be extracted from ash.

Ash Evacuation Systems:

The modern ash handling systems can be classified into four groups:

1) Mechanical System: This type of system is used for low capacity power plants. The hot ash comes out of boiler and is made to fall over the belt conveyor through a water seal arrangement. The cold ash fall on the belt conveyor is taken to the dumping tank and from there ash is disposed to trucks. The capacity of this type of system is limited to 5 ton per hour.
2) Hydraulic System: The hydraulic ash handling system carries the ash with a flow of water of high velocity through a channel situated below the hoppers and finally dumps the ash to sump. Depending upon the velocity of water this system can be divided in low velocity system and high velocity system. Low velocity system is widely used for simplicity in operation. The capacity of this type of system is about 50-ton pr hour.

3) Pneumatic Handling system: a high velocity air stream by an exhauster or vacuum pump at discharge end picks up the ash from all discharge point. Different ash removal equipment is placed in ash conveying path. The capacity of this type of system is about 45 ton per hour.

4) Steam Jet System: In this system of ash handling, the steam is passed through a pipe at a sufficiently high velocity, which is capable of carry dry ash. The capacity of this type of system varies up to 15 ton per hour.

Depending upon the ash collection at Bottom ash hopper or Air Heater hopper & ESP hopper, the collected ash is known as Bottom ash or Fly ash. Removal process of Bottom Ash and Fly Ash are given below: -

Bottom Ash Removal System: About 20% of total ash produced in furnace is collected at Bottom ash hopper. A trough seal arrangement is established between bottom ash hopper and furnace to arrest air ingress into furnace. Constant make-up water is given to bottom ash hopper for maintaining hopper water temp and slurry concentration to a certain limit. The continuous over-flow of bottom ash hopper is collected in a sump below bottom ash hopper known as Bottom ash Over-flow sump from where the ash-laden water is transferred to bottom ash trough of slurry sump or to ash plant clariflocculator by means of Bottom ash Over-flow Transfer Pump.

The bottom ash hopper may be ‘V’ type or ‘W’ (i.e. Double V) type. At BkTPP, the bottom ash hopper is double V or W type configuration with a common rectangular section at upper part and two integral V section at lower part. Each V- section consists of two sets of ash removal equipments, which are Feed-gate, eccentric crusher (also known as clinker grinder), Jet pulsion pump (simply jet pump) installed one after another in sequence. Out of these two sets equipment, one from each V-section is put into service for removal of bottom ash from bottom ash hopper and other set remains as stand-by.

During bottom ash removal process, High-pressure water from HP water pump header is charged to the jet-pulsion pump of the selected set after proper line-up i.e. isolation valve after jet-pulsion p/p kept opened. The eccentric Crusher/clinker grinder started after confirming its seal water. Then ash of bottom ash hopper is directed towards the clinker grinder through controlled opening of the Feed-gate. The feed-gate is hydro-pneumatically operated by means of an air-water converter tank and a 4- way solenoid valve. The two lines

(one from each V-section) convey the ash to the bottom ash trough situated above the slurry sump compartment and ultimately to the sump and from there to the ash pond area by means of ash slurry pumps. The Bottom ash hopper of BkTPP has a capacity of 150 ton and each lines of each V-section have a conveying capacity of 60 ton per hour. There are jetting nozzles placed at different location of each v-section for applying water jet for creating agitation or if any ash accumulation seen after completion of bottom ash removal. There are view glasses for seeing the inside of bottom ash hopper. The make-up water of bottom ash hopper is taken from low-pressure water header.

Coarse Ash Hopper Removal System: The coarser particles of flue gas are collected at 4 nos. economizer hopper due to change in velocity. About 2 to 4.5% of fly ash is collected at economizer hopper. Each economizer hopper outlet is connected to economizer surge hopper through a manual operated knife-gate valve and a trough type expansion joint. Continuous make-up water from LP water header is supplied to the economizer surge hopper and over-flow of this hopper is collected at bottom ash over-flow sump. Economizer surge hopper is of V shape, it has an outlet at bottom, this outlet is connected to bottom ash hopper through two nos. isolation valve one is manual and other is pneumatically operated. There are high pressure jetting provided at economizer surge hopper. The outlet valves on economizer surge hopper outlet line opened when Bottom ash removal process approaches to end. The coarse ash slurry discharged into bottom ash hopper is further disposed off by means of bottom ash removal equipments.

Fly Ash Removal System: The fly ash in flue gas is collected at 12 nos. Air Heater hoppers and 48 nos. ESP hoppers. This fly ash is removed in dry state from these hoppers and can be finally disposed off either in dry state or in wet slurry state. Under dry state disposal, the fly ash is ultimately collected and stored into station Silos and disposed off to the trucks. Under wet state disposal, the fly ash is mixed with water taken from HP water header in Wetting Heads to form slurry which ultimately taken to slurry sump of pump house under gravity and finally discharged to ash pond by ash slurry pumping system.
Another system known as ‘Silo By-pass’ in which ash going to Silo is diverted to Wetting Units where ash is made slurry by HP water and discharged to ash slurry sump if any emergency arise in Silo system due to non-availability of any equipment or anything else.
Fly ash removal from ESP and Air Heater hoppers is accomplished in two independent but inter co-ordinate operating system: -
Under the first phase of operation, fly ash from field hoppers is conveying either into an intermediate hopper known as Intermediate Surge Hopper (ISH) in dry state or into Wetting Head where ash is mixed with water to form slurry and discharged to slurry sump for further disposal.
Under second phase, pneumatic pressure conveying is deployed for transportation of dry ash from Intermediate Surge Hopper (ISH) to station Silo or Wetting Units and there-by completing the entire fly ash conveying route.
A) Fly Ash Vacuum Conveying System: 48 nos. ESP hoppers and 12 nos. Air Heater hoppers are grouped into three nos. ash conveying streams. First two rows of ESP hoppers of A-pass (i.e. 4nos.x 2 rows =8nos. hoppers) are connected to ‘B Stream’, similarly first two rows of ESP hoppers of B-pass are connected to ‘A Stream’. Rest 36 nos. ESP hoppers and 12 nos. Air Heater hoppers are connected to ‘C stream’. About 90 to 98% fly ash is collected in the first two rows of ESP hoppers (in both pass) and rest ash is collected in rest ESP hoppers. The first two rows ESP hoppers outlet valves (Ash Intake valve) are provided with diffuser type valve, rest hopper is with plain plate type valve. In all ESP hoppers there is provision of electric heaters arrangement and supply of hot fluidized air supply from ESP Fluidized Air Blower to make the accumulated ash in hoppers in dry fluidized state for ease in ash conveying. There are air in-take valve at end of each headers of each stream.
There are three nos. vacuum switches for smooth operation of ash conveying from each hopper. Depending upon vacuum produced in ash conveying system these vacuum switches operate.
Vs3-vacuum switch no -3 or known as high vacuum switch: say this switch is set at 350 mm of Hg, when vacuum in ash conveying line reaches 350 mm Hg or above, this switch operates and closes the ash intake valve (Hopper outlet valve) to avoid the over-loading the ash conveying line otherwise chokage in line may happen.

Vs2-vacuum switch no-2 or known as normal vacuum switch: say this switch is set at 200 mm of Hg, when vacuum of the system reaches to this set value, then this switch operates and again ash intake valve reopens and ash intake valve remains in open condition up to Vs3 value.
Vs1-vacuum switch no-1 or known as low vacuum switch: say this switch is set at 90 mm of Hg, when the ash in a hopper in a hopper is cleared and becomes empty, then vacuum of conveying line drops below the setting of Vs1, and then hopper empty annunciation appears. If this vacuum stays for certain duration (say 15 sec) the sequential step switch changes to next hopper and again ash conveying process is going on.
If vacuum value of the system lies between the setting of Vs1 and Vs2 for a pre-determined duration (say 15 sec), then 'hopper Plugged' annunciation appears.

i) Wet mode ash conveying: In the vacuum system under the wet mode, ash mixed with air in conveying line discharges into the Wetting Heads. One wetting head is dedicated to each stream i.e. there are 3 nos. wetting heads for 3 nos. ash conveying streams. In wetting head, high-pressure water is provided from high pr water header through a nos. of valves and orifices. In wetting head ash is mixed with water and becomes slurry. This slurry along with some conveying air is discharged into collection tank. From collection tank, the slurry gets discharged by gravity to a seal box and air is taken out from top of collection tank. This air may contain some amount of ash particles which are not mixed with water in Wetting Head. This air is washed by spray of clear water at Air Washer (one Air Washer for each stream). Clear water is taken from Clear water p/p discharge header. Now the clean air is discharged to Mechanical Exhauster (Vacuum P/P) and from Mech. Exhauster air is discharged to atmosphere through water separator and silencer. From seal box the slurry goes to the fly ash trough of ash slurry sump due to gravity. And finally the fly ash is pumped to ash pond area.

ii) Dry mode ash conveying: The dry mode ash collection consists of two parts: - a) collection of ash up to ISH by vacuum mode b) Transportation of ash from ISH to Silo by applying pressure-conveying system.
In dry mode, each ash conveying stream discharges ash to Filter Separator or Bag Filter (also known as Filter Vessel) which is an enclosed vessel containing with a series of filter bags. Ash particles are accumulated on the surface of filter bags and comparatively clean air passes through bag to the clean air plenum (chamber) of Bag Filter vessel. This clean air owing to existing vacuum in the conveying line, created by respective Mechanical Exhauster, passes through Air Washer of dry mode (separate air Washer for dry mode and wet mode) and becomes totally cleaned by spray water at Air Washer and finally discharged to atmosphere through water separator and silencer. The ash particles deposited on the walls of filter bags gradually choke the pores of filter bags. As a result, the pressure of dirty air plenum will increases; so, periodical cleaning of ash from bag surface is required and this done by an air jetting (known as Pulse Air Jet) to the bags. And ash is collected at bottom of Bag Filter vessel. The pulse air jet can be operated in 'timer mode' (at certain interval) or in 'DP mode' (depending upon pressure differential of dirty air plenum and clean air plenum). A fluidized airline from ESP Fluidized Air Blower is supplied to Bag Filter vessel for making the ash in fluidized state. The ash from Bag Filter vessel is taken to Transfer Hopper situated below the Bag Filter vessel through some discharge valve and equalizing valve. This Transfer Hopper acts as an intermediate vessel between Bag Filter vessel and Intermediate Sure Hopper. ESP fluidized Air line is provided in Transfer Hopper also. The ash from Transfer hopper of each stream discharges ash to a common big tank known as Intermediate Surge Hopper (capacity 120 Ton). Dry mode vacuum conveying system ends at ISH. After ISH, ash is conveyed by applying pressure conveying air taken from Conveying Air Blower discharge header. ISH is connected to 12 nos. Nuva-Feeder (air lock vessel) in two rows. The Nuva-Feeder assembly consists of a feeder vessel and two diffuser arrangements one at inlet and other at outlet of the feeder vessel. The upper end of top diffuser is connected to ISH and lower end of bottom diffuser is connected to the pressure conveying line provided below Nuva-Feeder.
During fly ash cleaning from ISH, ash is first directed from ISH into feeder vessel by opening top diffuser gate after enabling pressure equalization between ISH and feeder vessel. The top gate remains opened for a certain time after that top gate closed and bottom diffuser gate opens after equalization of pressure between feeder vessel and pressure conveying line. The ash is discharged to conveying line and is taken to Silo by pressurized air. ESP fluidized air and another hot air from Nuva-Feeder Fluidized Air Blower is supplied at Nuva-Feeder for making ash in dry and fluidized condition.

The conveying air laden with fly ash is discharged into Silo. And clean air is discharged into atmosphere through Vent Filter House situated at top of silo. From Silo ash can be taken out in dry mode through knife gate, orifice feeder and telescopic chute to closed vessel trucks. There is vent-fan for sucking out air from ash before discharging into trucks. Also there is a Rotary Unloader in each Silo for discharging ash from silo. A water spray is (taken from Unloader water P/P disch header) applied to suppress the dust during unloading ash through Rotary Unloader. Ash taken out from Rotary Unloader is of semi-dry type due to the water spray during unloading.
Also, another by-pass line on Silo line is provided which may be used if anytime during operation of pressure conveying system, Silo becomes not available for certain time. Here ash is taken to Wetting Unit placed above slurry sump and high-pressure water is used to mix the ash with water to make slurry and discharged into slurry sump and finally to ash pond area.

ASH SLURRY PUMP HOUSE

Ash Water System: For bottom ash removal and fly ash removal in wet mode, huge amount of water is required. For ash conveying raw water is used, and for sealing of pumps, other auxiliaries and cooling different equipments clarified water is used. There are two water sumps at ash plant pump house, one is Ash Water Sump and other is Clear Water sump. From ash water sump (capacity: 900 m³) HP Ash Water P/P (6 nos.), LP Ash Water P/P (6 nos.) and Unloader Water P/P (5 nos.) take their suction. And from Clear water Sump (capacity: 175m³) Seal Water P/P (3 nos.), Clear Water P/P (2nos.) takes their suction.
Ash water make-up requirement is 900 m³/hr.

HP Ash Water Pump: There are 6 nos. high-pressure ash water pump. These pumps are horizontal, split casing, flooded and double suction single stage and external clear water seal type. These pumps are driven by 6.6kv electric motor through flexible pin bush type coupling arrangement. HP water is required for: -

1. For conveying bottom ash and fly ash (i.e. at Jet-pulsion P/P and Wetting Heads).
2. For Wetting Units (at Silo by-pass).
3. For high pressure jetting at Bottom Ash hopper area, slurry Sump, and drain pit ejectors at different area.
4. Fly ash and bottom ash trough make up water.

All the p/ps disch are connected in a single disch header from where Hp water is divided to different area.
HP water P/P discharge capacity is 166.67 lit/sec (580 m³/hr).

LP Ash Water Pump: There are 6 nos. low-pressure ash water pumps. These pumps are horizontal, flooded end suction, single stage and external clear water seal type. This is driven by 415-volt electric motor through spacer love-joy type coupling arrangement. LP water is required for: -

i. Make-up water of trough seal, bottom ash hopper, economizer surge hopper bottom ash hopper over-flow sump.
ii. Ash slurry sump make-up and sludge sump make-up.
iii. Fly ash drain sump make-up and jetting.

LP water pump capacity is 83.66 lit/sec. (290 m³/hr).
In some power station, only single high capacity p/p is used instead of using two different types pumps. Here different types of pressure are obtained from main discharge header by using different diameter piping with orifices.

Unloader Water Pump: There are 5 nos. unloader water pumps. These pumps are used to supply water to Rotary Unloader of Silo to prevent ash spillage and nuisance while unloading dry ash from Silo by using rotary unloader. These pumps are horizontal, radially split casing double flooded suction type and driven by 415 volt electric motor.

Seal Water pump: There are 3 nos. seal water pumps. They supply seal water to HP Water P/P, LP Water P/P, Ash slurry P/P and Sludge P/P. These pumps are horizontal, radially split casing, four stage and driven by 415 volt elect motor.

Clear Water Pump: There are two nos. clear water pumps. These pumps supply water :-

i. For cooling oil of the fluid coupling of ash slurry pumps.
ii. For sealing silo drain p/ps.
iii. For sealing of Clinker Grinder, Bottom Ash Over-flow Transfer p/p, fly ash drain pump.
iv. For water spray in Air Washer.
v. For cooling Instrument Air Compressor.
vi. For cooling oil of gearbox of Conveying Air blower.
vii. For cooling Nuva-Feeder fluidizing Air blower.

These pumps are horizontal, flooded end suction and single stage type.

Ash Slurry Pump House: There are 6 nos. compartments (ash slurry sump) of which first four are for Unit#1 and unit#2 and rest two are for Unit#3.Above the slurry sump compartments, there is a trough divided in two parts known as Bottom ash trough and fly ash trough. By operating plug gates of this trough, we can select the respective compartment of our choice from where ash can be taken to ash pond by ash slurry pumps.

Ash Slurry Pump: Each of the compartments of slurry sump consists of a slurry pump set where two nos. ash slurry pumps are kept in series. The series pump is used for boosting the disch pressure so that ash can be conveyed to ash pond, which is situated at long distance from main plant. More over there is a provision of third pump to be kept in series if there is any requirement in future. Each pump consists of a fluid coupling by operating which we can vary the discharge rate of slurry pump as per our requirement depending upon sump level. Also make-up water is provided from LP water header to each of the compartment of slurry sump. Ash Slurry pump are horizontal and double casing type and driven by 6.6 kv electric motor through fluid coupling.

Discharge rate of ash slurry p/p generally varies from 650m³/hr to 550m³/hr.

Ash Conveying Pipe Lines: There are four nos. ash slurry-conveying pipes by which ash slurry can be pumped by ash slurry p/ps to the ash pond area. Cast Iron pipes are best suited for ash slurry conveying due its high wear resistance properties but cast iron pipes cannot be welded easily, so maintenance work if any pipe breakage occurs will be very difficult that is why C.I pipes are practically not used. Instead of that Mild Steel (M.S) pipes are used. And occasionally certain length of pipes is rotated by certain degree (say180deg) for maintaining wear and tear equally throughout the circumference. Interchangeability of using any pipe by running any set slurry p/p is there, but one pipe can accommodate only one p/p discharge. So, care must be taken regarding the selection of slurry p/p set and pipe before starting the slurry p/p, otherwise pipe may break. Maximum wear occurs at bent portion of pipe since there is change in direction of flow, so, a hard metal coating (lining) is used in bent portion, and generally 'Basalt' lining is used for this purpose.

Water Recovery System at Ash Plant Area: A large quantity of water is required in ash plant for ash conveying during bottom ash removal or if wet system of ash removal is used. For disposing ash in slurry state about 70 to 80 % of water is required for 20 to 30% ash. So, use of less water and recovering /recycling of previous used water is getting more emphasis in modern power station. Ash Slurry P/P discharges the ash slurry to ash pond area where ash settles down from ash slurry and water is collected in a sump. This water is chemically impure and may contain minute's particles of ash and this water is pumped back by 3 nos. Water Recovery pumps at Recovery Pump House of ash pond. The water is returned at Clariflocculator of ash plant where chemical treatment and sedimentation of suspended particles of that water is done and finally collected at a storage reservoir known as 'collection well'. From collection well this water is transferred to ash water sump by 3 nos. Recycle Water P/P.

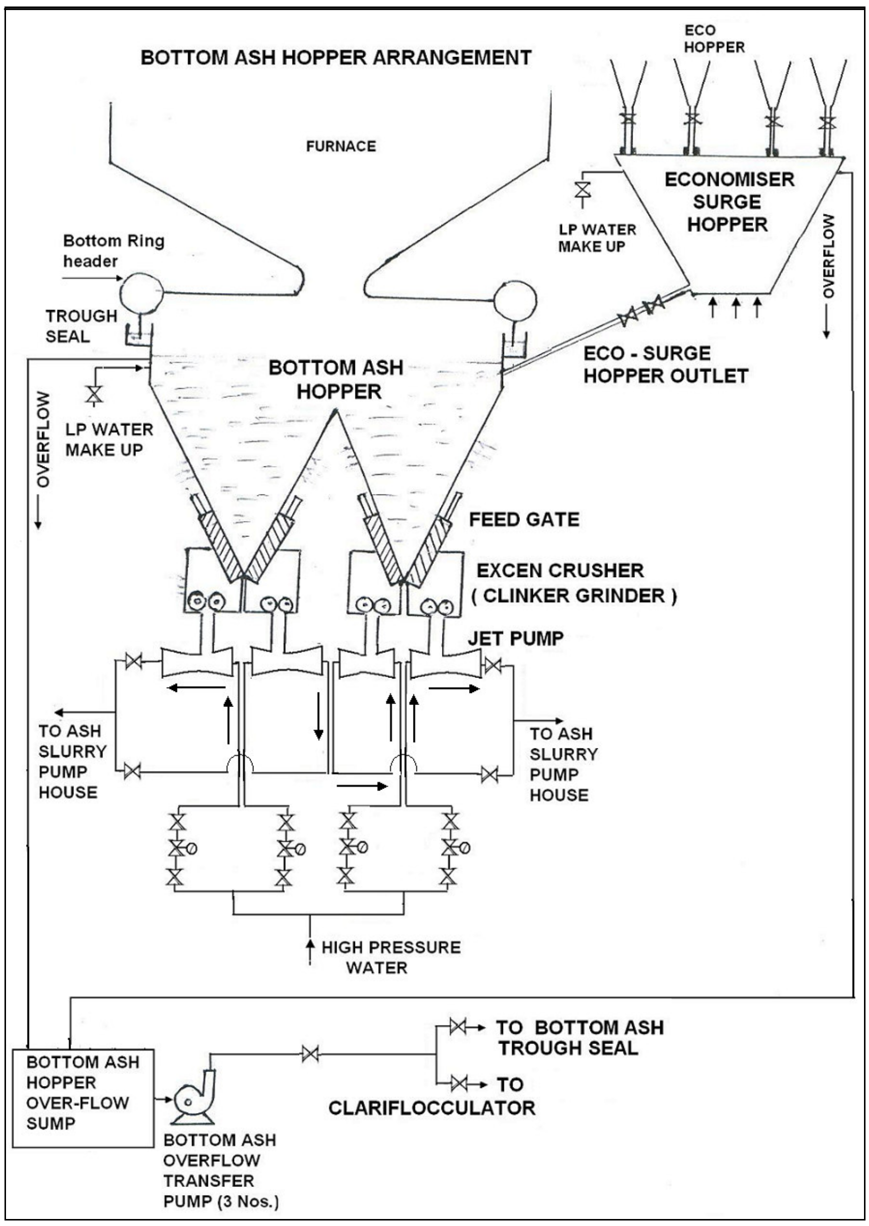
Also, a large amount of water is given as a continuous make-up at Bottom Ash Hopper and Economizer Surge Hopper; as a consequence a continuous over-flow is happening from the two hoppers. This water contains some ash particles and is collected in a sump below the bottom ash hopper known as 'bottom ash over-flow sump'. This ash-laden water is transferred to either bottom ash trough or clariflocculator of ash plant. If water is taken at bottom ash trough, then this water mixes with slurry and goes to ash pond and again returned back by water recovery system. And if the water is taken into clariflocculator of ash plant, then the water is recovered through collection well as stated earlier.

Similarly, during using Dry System, spray water of air washer of dry mode is collected in a sump known as 'fly ash drain sump'. This water also contains little amount of ash particles and transferred to either fly ash trough or to clariflocculator of ash plant and again recovered as stated above.

Conveying Air Blower System: There are two nos. conveying air blowers for supplying conveying air to Nuva-feeder outlet for pushing ash to Silo. One blower puts into service and other remains as stand-by. This blower takes air from atmosphere and compress to higher pr. These blowers are driven by 6.6 kv motor and there is a gearbox for reducing speed to blower The gearbox is cooled by clear water-jacketing.

ESP Fluidized Air Blower System: There are two nos. air blower and heater arrangement for heating that air and supplies to each ESP hopper, Filter vessel, Transfer Hopper, Intermediate Surge Hopper and Nuva-Feeder for making ash in dry, fluidized state for easy free flowing. One blower puts into service and other remains as stand-by.

Nuva-Feeder Fluidized Air Blower System : There are two nos. nuva-feeder fluidized air blower for supplying fluidized air to each nuva-feeder for making ash free flowing. These blowers are two stage blower and compressed air in first stage is cooled by clear water. One blower puts into service at a time.



30
PULVERISER & FAN PERFORMANCE

PULVERISER

Pulverisers are selected to provide a required grinding capacity, based upon a set of design criteria that include the required coal particle fineness and coal characteristics. The required pulveriser capacity is determined by the boiler heat input requirement, with some additional allowance added to account for wear of the mechanical parts. The required fineness is a function of specific coal properties such as the volatiles in coal and the rank of coal. It is also a function of the type of burners, firing system and furnace size. Coal characteristics like grindability, moisture, ash that determines the mill performance.

Pulveriser guarantees :

Pulveriser performance test is carried out for getting the followings :

- Pulveriser output, T/hr. at a specified level of fineness i.e. 70% passing through 200 mesh.
- Power consumption KW/T of coal at specified level of fineness.
- Wear parts guarantee.
- Capability to operate two adjoins pulveriser at 50% load without oil support.
- Turn down ratio.

Objective of mill performance testing:

- Uneven distribution of pulverized coal to burners operating in parallel adds to combustion problems such as flame blow out, excessive NOx formations, low burnout, combustion oscillations and uneven combustion across the furnace, which leads to poor plant performance. To avoid this combustion problem and to get better output of mill, performance test is carried out.
- To ensure wear life of grinding rings and balls.
- To minimize mill rejection.
- To minimize power input.

Factors affecting the mill performance:

Coal hardness (Hard grove index –HGI): Higher HGI means that mill can grind more coal to the same fineness or the same amount of coal to a greater fineness. This property of coal is measured by grindability index, which is inversely proportional to the power required to grind the coal to a specified particle size for burning. Grindability of a standard coal is defined as 100 i.e. HGI -100. If HGI-50 coal is used then grinding power would be twice of that power required for 100 HGI coal for same fineness. In BkTPP coal HGI varies from 45 to 55. This variation of coal quality in hardness changes mill performance **(See Fig- M1)**

High ash content in coal: If high percentage ash coal is used then Pulveriser loading increases and subsequent erosion causes performance degradation.

Primary air flow and temperature of air at inlet to the mill: Proper rate of air flow is determined by mill calibration otherwise less airflow is the cause of mill packing and high air flow affects the coal fineness at mill outlet.
Moisture content in coal: The total moisture content of raw coal is made up of hygroscopic moisture (inherent –within the coal) and free moisture. If coal with a higher moisture content are handled a progressive fall off in mill output. High moisture content leads to mill outlet temperature low, mill packing, high mill DP & coal pipe choking.

So, more primary air is required for same feeding. Due to low mill outlet temperature and high mill differential pressure, feeding of mill is restricted. So, high moisture in coal is the cause of degradation of mill performance.

Fig- M2 shows that grinding capacity of Mill decreases , if moisture content in Coal increases.

<u>Fineness of coal at mill outlet:</u> Normally classifier is installed in the mill outlet circuit, which will return back higher size particles back to the mill for regrinding. As the fineness of coal changes the combustion condition and efficiency, this has to be kept at minimum value. 70% to 75% of product passing through 200 mesh (75µ) is normally found suitable for most of the coals.

Mill output varies inversely with fineness. Hence, mill output can be increased just by reducing the fineness. **See Fig- M3**

<u>Size of raw coal:</u> The larger the size of raw coal fed to the mill, the greater the energy required to break it down. For a constant energy input, mill output will vary according to the size of coal. A coal supply of a finer grade will result in an increased output from the mill, while coarser grade will produce a reduction in output.

<u>Calorific value</u>: Calorific value of coal does not have any bearing on the mill capacity. But calorific value is one, which dictates the quantity of coal to be milled per boiler for a particular output. Hence, variation in calorific value of coal varies the number of mills to be kept in service or loading on each mill for the same output of Boiler.

<u>Mill wear:</u> Mill output tends to fall off as wear increases on grinding surfaces. So, grinding surfaces are replaced after a certain period of running to avoid degradation of mill performance.

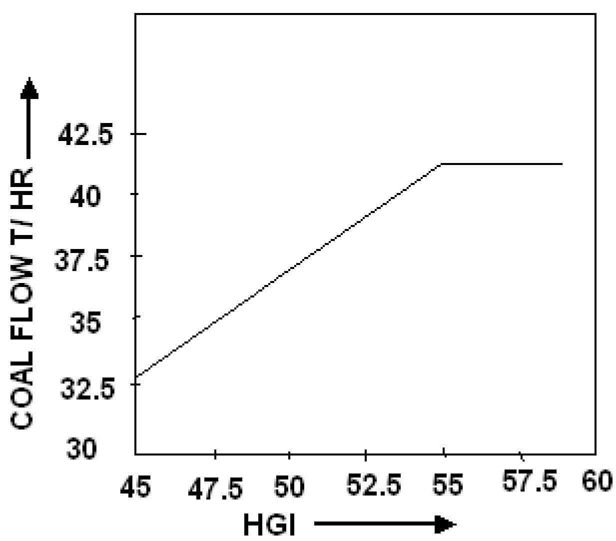


Fig.: M1

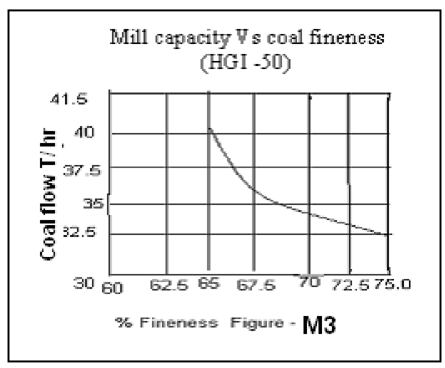


Figure - M3

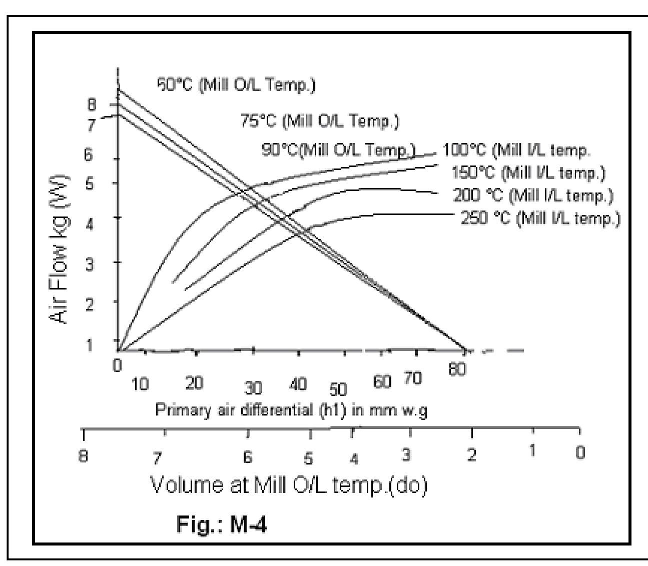


Fig.: M-4

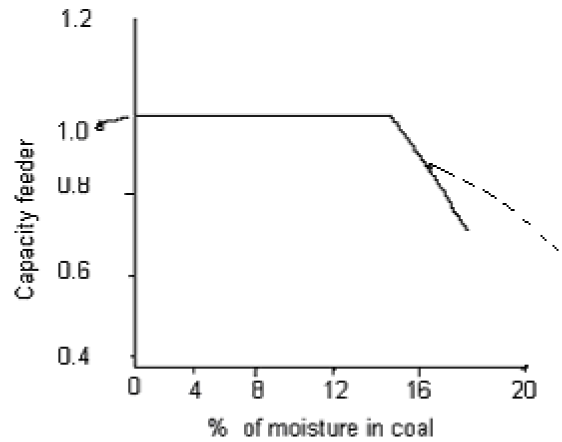


Figure - M2

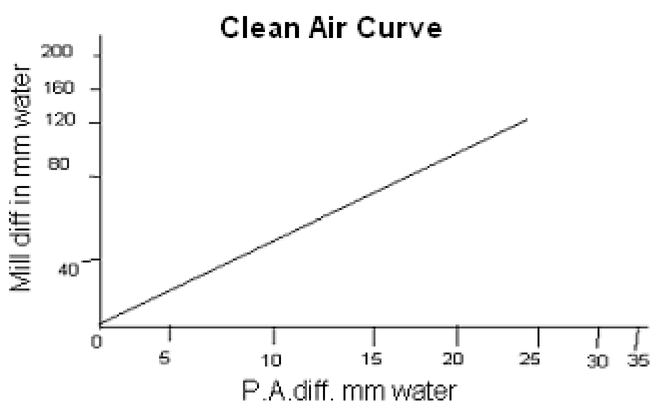


Fig.: M5

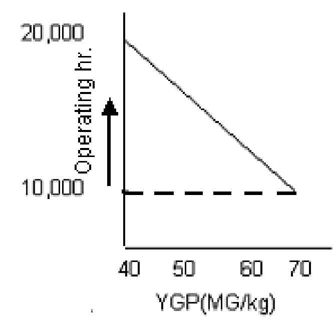


Figure - M - 8

Mill output Vs Air Flow Curve

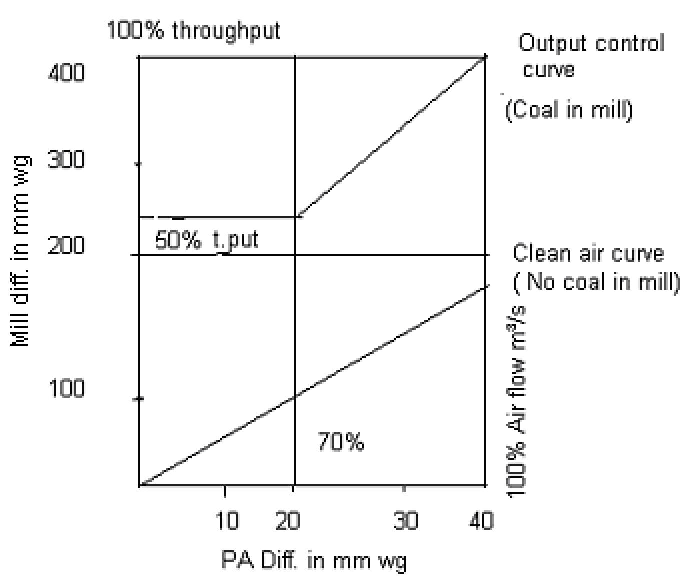


Fig.: M6

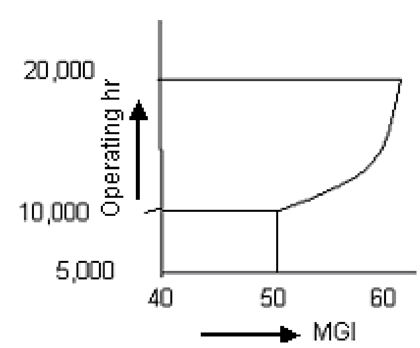


Figure - M7

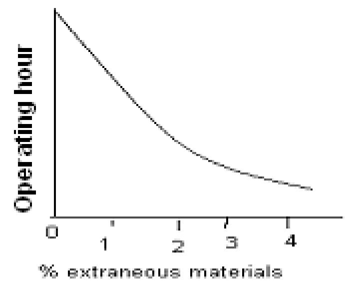


Figure M - 9

The ambient temperature and raw coal temperature will affect the mill performance to a lesser extent. The performance of the mill is governed by the following operating parameters that need to be assessed accurately:

- Mill outlet temperature.
- Mill airflow
- Accuracy of gravimetric feeder
- Raw coal size
- Mill differential pressure
- Mill power
- Mill calibration is done by (A) clean airflow test, (B) Dirty air test.

(A) Clean airflow test - It is the calibration of mill primary air measuring equipment. Normally the airflow-measuring device is an orifice plate, venturi or aerofoil. This device is situated in the duct between primary air fan and mill.

The purpose of the calibration is to determine the rate of air flow in the system at any time so that design conditions can be achieved as far as the following are: -
(a) Burner velocities
(b) Fuel air ratio
(c) Minimum fuel pipe velocities.
Required test equipments are: i. a pitot tube ii. manometer (U tubes and an inclined draught gauge) & iii. Thermometers or thermocouples for measuring the temperature of the air at the pitot traverse location and at the permanent PA differential measuring device.

Procedure :

Clean airflow test is carried out by running PA fan only. Mill feeder may not be run during the test. The calibration consists of measuring the airflow through the system by means of pitot tube traverse in a coal pipe. Since the velocity of air passing through a pipe varies from the wall to the centre of the pipe, pitot reading at any one point will not be representative. Two traverse should be made across the diameter of the pipe at right angles to each other. Airflow measurement of coal carrying pipe is done at inlet to burner.

It is recommended that before any actual air measurements are made, the permanent primary air-measuring device be investigated for possible critical range. This is accomplished by opening the primary air damper very slowly while the fan is running and observing the action of the primary air differential .

MEASUREMENTS:

While the traverse data is being taken, the following readings necessary for the calculations.
Air temperature t_o at the location of the pitot tube traverse and at the permanent measuring device, t_1.
Static pressure in the coal pipe at the location of the pitot tube traverses and at the permanent primary air-measuring device.
Primary air differential by monometer, h_1.
Mill differential by manometer.

Velocity heads, h_o, by pitot tube traverse in the burner pipe.
PA fan discharge static head.

CALCULATIONS :

Airflow velocity is obtained from this formula:

$v = 2gh$ Where, v = Average velocity in m/sec.
g = Acceleration due to gravity
h = Head in m of airflow.

Head of air flow, $h = \dfrac{h_o \times d_w}{d_o \times 10^3}$

Where ,
h_o = measured velocity head pitot tube in mm of wg
d_o = density of air in kg/m³ at the pitot tube traverse
d_w = Density of water ,10³ kg / m³

So, velocity , $v = \dfrac{2 \times 9.81 \times h_o \times 10^3}{d_o \times 10^3} = \dfrac{4.43}{} \times 2 \dfrac{h_o}{d_o}$ m / sec.

The air density at 0°C and 760mm Hg = 1.29 kg / m³

The air density at the pitot tube traverse = d_o

$$d_o = 1.29 \text{ X } \frac{273}{d_o + 273} \text{ X } \frac{\text{Absolute pressure}}{760}$$

Where, t_o = air temperature at pitot tube traverse in ° C
Absolute pressure = Atmospheric pressure + static pr. at the point of measurement .
Pressures are measured in mm of Hg.

Calculation of calibration constant k

A calibration constant k, which is a function both of the type of permanent PA measuring device and the physical dimensions of the PA system at that point is calculated from this formula ;

$w = k \quad h_1 d_1$

Where, w = air flow in kg/ Sec.
d_1 = density of air at the permanent PA measuring device in kg/m³ at that temperature .
h_1 = PA differential indicated by permanent PA measuring device.
The weight of air flowing in kg / sec. (w) at the pitot tube traverse is w = Avdo
A = area of coal pipe in m².

$$K = \frac{w}{h_1 d_1} = \frac{Avdo}{h_1 d_1}$$

Value of k should be calculated from each set of traverse readings at the different airflow rates. From the set of k data, average k value is taken.

PA differential (h_1) $_{VS}$ weight flow curves:

With this value of k (average value) airflow is calculated by using this formula
$w = k \quad h_1 d_1$
From the values for the air weights w and the primary air differential (h_1) a family of curves for the several mill inlet temperatures is plotted **.**

M³/Sec. Vs weight flow curves:

To plot the curve kg of air per sec versus cubic meters of air per sec for various mill outlet temperatures it is only necessary to select some arbitrary weight flow rates of air such as 2 and 6 kg / sec. and apply the formula

$Q = w / d$ where d = density of air at mill outlet temp.

These curves can be used to derive PA differentials from stated air flows at given mill inlet and outlet temperatures. The calibration is a reference for comparison at any future date when mill performance may be under investigation. The calibration should also be repeated to check that there is no change in k value after any disturbance of the PA measuring device.

Clean air curve:

It is the figure drawn between PA differential Vs mill differential **.**

Mill output Vs airflow Curve:

The difference in mill differential between the two curves is a measure of coal in the mill and at any given point is related to the mill output. **.**

(B) **Dirty Air Test :** A dirty air test is performed with the Pulveriser operating at normal full load conditions . This is exactly the same process described in clean air test except the following :

(a) A dirty air probe is used through the dustless connector to get traverse data instead of pitot tube. Velocity and coal fuel airflow are calculated by using same formulae used earlier.

Mill capacity test:

This test is carried out for checking the mill performance at maximum coal feeding.

Guarantees :

The coal throughput of 36.54 t/hr can be produced at product fineness of 70% passing 75 μ (200 mesh) whilst grinding coal with HGI of 50 and moisture content of 10%.

Demonstration:

A one time demonstration of coal throughput of 40.6 t/ hr will be done at a product fineness of 65% passing 75 micron whilst grinding coal with HGI of 50 and moisture content of 10%.

Pre-test preparations:

Prior to the performance test being carried out the following shall have been completed.

Coal feeder Inspection:

An internal inspection of the coal feeder shall be carried out and any defects will be rectified prior to the feeder being calibrated.

Calibration of Coal Feeders:

The coal feeder shall be calibrated by weighing the amount of coal discharged from the feeder during a set time with the feeder operating at a fixed speed.

Mill Inspection:

The coal mill shall be inspected internally and externally prior to the test. All critical dimensions shall be recorded and any defects rectified prior to the test.

Calibration of Primary Air Flow:

The primary airflow measurement device shall be calibrated prior to the performance test.

Clean air curve:

The clean air curve for the mill shall be determined prior to the performance test.

Coal quality:

Coal of the correct analysis and size distribution shall be supplied to the raw coalbunker in sufficient quantity to ensure that this coal is fed to the mill during the entire test.

Operating conditions:

The coal feeder speed, mill air flows and temperatures shall be set as near as possible to the guaranteed operating conditions.

Mill Rejects:

The mill reject boxes shall be emptied immediately prior to the test and the time recorded.

TEST PROCEDURE

Test Period:

A period of two hours shall be allowed for operating conditions to stabilize and initial readings to be taken to ensure that the correct operating conditions have been attained.

The test period shall be a minimum of two hours or until pulverized fuel sampling is completed.

Test Readings:

Readings shall be taken for a period of one hour before and after the test period to ensure that stable conditions are maintained.

The following readings shall be recorded at 10 minutes intervals using both local test instruments and control room panels:

1. Primary airflow measuring device differential pressure.
2. Mill differential pressure.
3. Mill I/L air temp.
4. Mill O/L temp.
5. Coal feeder speed
6. Mill motor current
7. Mill motor volts
8. Primary air fan current
9. Mill I/L pressure
10. Classifier I/L pressure
11. Classifier O/L pressure
12. Mill Power.

Coal sampling:

Raw Coal samples shall be taken from the feeder every 15 minutes during the two-hour test period. All samples shall be stored in labeled, airtight buckets for subsequent analysis.

Mill reject sample:

The mill reject boxes shall be cleared immediately prior to the test and the time recorded. Similarly, the boxes shall be emptied at the end of the test and the time recorded. The mill rejects collected during the test shall be weighed. Samples are stored for analysis.

Pulverised fuel (PF) :

A Sample of pulverized fuel shall be obtained from each mill O/L pipe using isokinetic procedure.

Analysis of results:

6.1 **Coal analysis.**

Proximate analysis	**Ultimate analysis**
(a) Total moisture	(a) Moisture
(b) Volatile matter	(b) Carbon
(c) Fixed carbon	(c) Hydrogen
(d) Ash	(d) Sulphur
	(e) Nitrogen
	(f) Oxygen
	(g) Ash
	(h) Calorific value

Hard grove Index (HGI)

Abrasion Index

6.2 **Mill capacity :**

The mill capacity shall be determined by calculating the average feeder speed during the test period and by reference to the feeder calibration data taken prior to the test. The as run mill capacity shall be adjusted for variations in HGI and PF fineness. **Refer Fig. No. M1 &** M7 .

Mill capacity with respect to feeder speed:

Feeder Speed - Minimum speed 180 rpm = 9 T / hr.

- Maximum speed 900 rpm = 45 T / hr.

Mill capacity - 36.5 T/ hr.(rated) 40.6 T/hr. (max.)

i.e. 20 rpm of feeder speed is equivalent to 1 T feeding (approx.).

PF Fineness :

6.3 The fineness of the mill product shall be determined by dry sieving

6.4 **Mill Rejects :**

The calorific value of the mill rejects shall be determined. The heat value of the rejects (KJ/ hr.) shall be determined according to the formula.

$$\text{Heat value} = \frac{W_f \times GCV}{T}$$

W_f = Total weight of rejects during test period kg/ hr.

GCV = Gross calorific value KJ/ kg

T = Time of test period (hr.)

6.5 **Power Consumption :**

The power consumption of the mill shall be calculated according to the formula

$$\text{Power} = 3\, I_{av} .\, V_{av} .\, \Phi \,.\, \eta$$

I_{av} = Average motor amps during the test period

V_{av} = Average motor volts.

Φ = Motor power factor

η = Motor efficiency

Alternatively KWH meter reading by using energy meter can be used to determine average power consumption.

6.6 **Mill product temperature :** The mill product temperature shall be determined as the average of the mill product temp. Recorded during the test.

MILL WEAR LIFE GUARANTEE:

The wear parts for the mills of 10E10 type which are used in this project are guaranteed for 10,000 hours where grinding the design coal at 100% BMCR flow rate with 4 mills in service.

The wear life of the grinding rings and balls is influenced / affected by variations in coal size, HGI, YGP Index of abrasiveness, and the presence of extraneous material like rock, stones, ash etc.

Two basic mechanisms of mechanically induced wear are present in the grinding zone.

First mechanism is abrasion caused by solids moving over a surface. With additional loading as supplied by the mills, pneumatic loading system high stress abrasion wears deteriorates wear life of grinding element.

Second mechanism is impaction erosion wear where the energy for removal of surface material is provided by the kinetic energy of impacting coal particles. It is considered to be negligible if mill is operated smoothly or correctly.

Coal mill also suffer to a degree of **chemical wear** i.e. corrosion in a moist atmosphere. Sulphur (oxidized pyrite) and chlorine (chlorine and sodium ion) compound and organic acids constitute an acidic and corrosive medium in moist coals. In addition, it is fact that water in the absence of acids can enhance abrasion wear. It appears that surplus water in an optimum concentration will constitute a corrosive (oxidant) medium for some materials when acting together with abrasion or erosion / wear causing particles. This form of grinding element material loss is considered however to be small for the specified range of moisture in the raw coal feed to the mill.

Factors affecting the wear life of grinding material:

(1) The wearing characteristics of a coal depend on its content of hard minerals, the most important being pyrite and quartz. If the presence of these materials is high in coal then wear will be high. Except this followings are also the factors:

(a) **Feed size of the abrasive constituents in the coal-**

The larger the size of the quartz and pyrite particles the longer they remain in circulation in the mill, hence wear rates are increased.

(b) Density **of abrasive constituents -** high-density quartz in coal increases wear rate.

(c) **Shape of abrasive constituents –** Rounded quartz particles have been found on investigation to cause higher wears than that resulting from angular particles.

2) **HGI of coal :** If high HGI coal is used then wear rate is reduced .

3) **YGP Index (Abrasion Index) :**

Abrasion Index is measured in YGP testing machine.

It is measured as presence of abrasive material per Kg of coal i.e. mg / kg of coal. If YGP index increased then wear rate also increases. **See figure M8**

YGP index varies from 45 to 65 .

4) **Percentage of Extraneous material present in coal** : The presence of extraneous material is determined by sink float testing in a liquid of specific gravity of 1.6. Percentage increase of extraneous material in coal increases the wear rate. **See Fig. M-9**

Moisture in Coal :

More moisture in coal constitutes a corrosive (oxidant) medium for some materials acting together. When more moisture content raw coal feed to the mill then grinding materials suffer from a little amount of corrosiveness and loss of grinding materials occur.

Mill ball size at various conditions:

New ball dia 772 mm . When ball dia reduces to 700 mm then another ball is added. Total no. of balls - 10 + 1 = 11. When ball size reduces to 578 mm then all balls are replaced by 10 nos. of new ball of 772mm dia.

Mill performance monitoring using non isokinetic sampling

Non iso-kinetic sampling technique is extensively used currently to monitor Pulveriser performance. Feed back on mill fineness level along with unburnt loss in bottom ash and fly ash are taken into consideration for corrective action. This is a very effective approach for trending mill performance on a regular basis and to study its impact on boiler performance, as dirty air testing cannot be undertaken at such a regular frequency. To establish this performance trending on a proper footing a specific format should be used to collect the database and a proper record of this data should be maintained for each mill to understand the observed deviations and the probable causes.

Coal fineness analysis:

This analysis is the best performed directly after sample extraction to prevent coagulation of sample due to moisture absorption especially for samples drawn from the mills handling high moisture coal.

Procedure:

1) Roll the sample bag to provide a proportionate sample.
   Remove 50 gm of coal from the sample.
2) Shake this 50 gm of sample through a series of 50, 100 and 200 mesh.
3) Record the weight of coal residue on each of the three screens and bottom catch pen.
4) Calculate the percentage of sample passing through each mesh using the
   Following equations:

Weight of test sample	50 gm
Weight of Residue on 50 mesh	R_1 gm
Weight of Residue on 100 mesh	R_2 gm
Weight of Residue on 200 mesh	R_3

% Passing through 50 mesh $\dfrac{(50-R_1)\times 100}{50}$

% Passing through 100 mesh $\dfrac{50-(R_1+R_2)\times 100}{50}$

% Passing through 200 mesh $\dfrac{50-(R_1+R_2+R_3)\times 100}{50}$

% Recovering $\overline{50-(R_1+R_2+R_3+R_4)\times 100}$

In this way mill product fineness has been checked in every one-month interval and accordingly maintenance is done if fineness falls below required level (70% passing through 200 mesh).

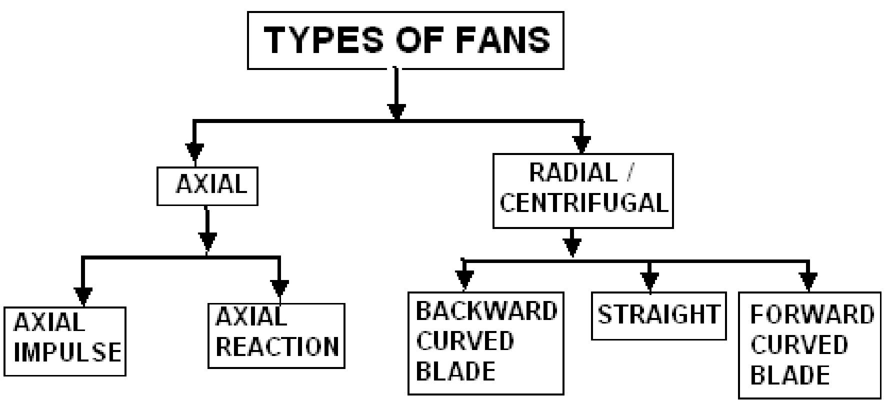
F A N

GENERAL :

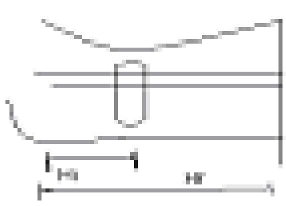
Fans are the most important auxiliaries in a boiler system. Regardless of fuel and method of firing, all boilers for power generation use mechanical draft fans. They supply the primary air for the pulverization and transport of coal to the furnace. They also supply the tertiary air and the secondary air to the wind boxes for complete combustion. Fan also remove the products of combustion from the furnace and move the gases through heat transfer equipments. Numerous small fans are used for sealing, cooling of igniters, scanners and other equipments.

A fan is a volumetric machine, which moves quantities of air or gas from one place to another. The fan imports to the medium enough energy to set it into motion and to overcome all resistance to flow in its path.

Types of fans :



Axial Fan: The axial fans basically consist of an impeller on the periphery of which the blades are mounted. The impeller draws the medium from a suction chamber imparts energy and discharges the medium into a diffuser. At the outlet of the diffuser the necessary head is obtained.
Axial fans are classified as axial reaction and axial impulse fans based on how the energy is imparted to the medium when it flows across the fan.



H_i - Head developed across the impeller.
H_f – It indicates the pr. difference between outlet of fan diffuser and suction chamber.
Head developed across the fan

Degree of reaction = Hi / Hg

If the degree of reaction is less than 0.2 then this fan is called axial impulse fan. In case of axial reaction fan degree of reaction will be around 0.8.
The reaction fans are provided with profile blades wherein the blade crosses section varies continuously from root to tip. The impulse fans have non-profile blades wherein the blade cross-section uniform. So axial reaction fans are called axial profile bladed fans (AP fans) and impulse fans as axial non-profile bladed fans (AN fans). The pressure and flow output is controlled by a adjusting the pitch of the fan blades. These are

called variable pitch blades. This type of fan used as force draft fan. Axial fans can maintain higher efficiencies at various steam generator loads.

Blade pitch control: This type of control is used only in axial reaction fans. The flow is controlled by varying the blade angle of the fan. The effect is to create a unique aerodynamic configuration for the fan at each point of operation so that the fan is operating at maximum possible efficiency.

As the blade is adjusted from minimum to maximum position the flow change is nearly linear. Further the response is very quick. The blades can be moved from the maximum open to fully closed position in 30 seconds. This means the fan can respond from maximum continuous condition to zero flow is approximately 20 seconds.

Centrifugal Fan / Radial Fan :

Centrifugal fan blades are mounted in an impeller that rotates within a spiral housing. Centrifugal fans move air or gas perpendicular to the impeller shaft.

Working principle:

The medium handled is drawn into the eye of the impeller and the centrifugal force of the impeller throws-out the medium radially. The blades impart kinetic energy to the medium. When the medium flows through the spiral casing this kinetic energy is converted into potential energy.

There are three basic blade types in centrifugal fans. The angle between the blade tip and direction of rotation is known as blade angle. When this angle is less than 90° it is forward curved, when it is 90° it is straight radial and when it is greater than 90° it backward curved.

Normally backward curved centrifugal fan is used as ID fan.

Advantages of backward curved centrifugal fan

Highest efficiency, over 90%
Very stable operation
Low noise level
Ideal capabilities for high-speed service
Non-overloading horsepower characteristics.

System Resistance :

When a gas is forced through a duct system, a loss in pressure occurs. This loss in pressure is called system resistance. System resistance is composed of two components.

Friction losses : It occurs at the walls of the duct system due to friction.

Dynamic losses: It occurs due to changes of direction in gas flow and at sudden duct enlargements and contractions. Dynamic losses can also call velocity pressure losses.

$$\Delta P \ (\text{Friction}) = \frac{FLV^2}{2gd} \times \rho$$

$$\Delta P \ (\text{dynamic}) = \frac{\rho V^2}{2g} \times \frac{1}{2} k$$

K = system constant based on the geometry of the duct system most accurately determined by actual testing. System resistances changes directly with changes in gas density and is directly proportional to the square of volumetric flow changes.

FAN PERFORMANCE :

Fans are used to provide the pressure necessary to overcome system resistance. Fan performance characteristics are developed from test data and are typically illustrated on flow Vs static pressure curves similar to those used to show system resistance.

Once the fan is installed into a duct work system, the intersection of system resistance curve and the fan characteristic curve defines the system operating point.

Fan efficiency approaches zero when the fan operates at zero flow and shut off head and also approaches zero at maximum flow conditions where the static pressure approaches zero. Fan efficiency is calculated from test data and is a ratio of the air horse power to the actual shaft bhp requirement.

For performance curve (centrifugal fan, backward curves):

Fan performance curve are developed by testing model fans. The results of model fan tests are used as a basic for determining the performance capabilities of full-size geometrically similar fans. Three basic relationships between fan size, fan speed and gas density are the bases for predicting full size for fan performance

Centrifugal fan operating characteristics:

I/L damper / vane control: Inlet damper or Inlet vane centrifugal fan control is used with variable speed control system. The dampers or vanes are full open for full flow and as the dampers or vanes close, the fan flow and pressure capacities are reduced. The inlet dampers or inlet vanes, when partially closed, impart a preswhirl on the flow stream entering the fan in the direction of rotor rotation. This preswhirl reduces the relative velocity of the fan blades to the air streams, thus including the fan flow and pressure capacities. This preswhirl also reduces the fan power requirement.

Determination of fan performance with inlet dampers at partially closed positions is accomplished by fan performance testing. This test are normally performed by the manufacturers on reduced - size scale model fans and are then estimated for the full size fan performance.

Variable speed operation:

Variable speed operation provides the ultimate in power savings at reduced load operating conditions. When variable speed is used to regulate flow, the fans are not required to overcome pressure drop across partially open dampers. This results in fans that can maintain maximum efficiency across the entire system operating range.

SURGE:

The surge limit of a centrifugal fan is that point near the peak of the pressure curve corresponding to the minimum flow rate at which the fan can be operated without instability.

Axial fan operating characteristics:

Axial fans are normally controlled by adjusting the blade pitch. A characteristics performances field for a typical constant –speed, variable pitch axial flow fan is shown in the figure. Each blade pitch angle results in a specific flow VS head characteristic curve..

As the blade pitch angle is increased, the pressure and flow capacity of the fan also increase. Once installed in a system, the flow through the fan can be controlled to any condition in its performance field, provided the fan drive motor is of sufficient horsepower.

Stalling:

Stall is the aerodynamic phenomenon that occurs when fan operation is attempted at a condition that is beyond the fan pressure capacity. When the fan blades are required to provide more static pressure rise than they are designed to produce (due to sudden increase of system resistance by any reason), flow separation occurs around the blade. Centrifugal force then throws air trapped in this separated portion in a radial direction, to the outer tip of the blade. At this point pressure builds up until it is relieved through the blade tip clearance. This process creates a very unstable and oscillating pressure force on the blade and can cause very sever vibrations throughout the entire fan. When this occurs, the fan becomes unstable and no longer operates on its normal performance curve. Operation in this stall condition is accompanied with increased noise and vibration. Continuous operation in this condition leads to fatigue failure of the rotating blades because of the high frequency vibrations the blades encounter during stall condition.

According to the curves figure F6, N are the normal fan performance curves for a constant blade angle. Each blade angle characteristic curves has its individual stall point, marked as ‘S’. The curve connects the stall points of the individual blade angle characteristics curve is referred to as the stall line. If the normal operating system résistance increases for any reason the normal operating point ‘X’ will change to overcome the higher system resistance. For a given blade pitch angle, the fan operating point will move along the static pressure curve to meet the new pressure requirements. If the pressure increases to the stall point the fan will stall. Once the fan enters the stall condition, performance will remain unstable until the system resistance returns to normal or the blade pitch angle is reduced until the fan regains stability. The fan will be stable when the static pressure capability at the reduced blade pitch angle provides a stall point ‘S’ that is higher than the pressure required by the new system resistance (SR_2). If stabilization cannot be attained by blade adjustment, the fan must be shut down to avoid damage to the fan rotating components.

Prevention of stalling:

Axial fan should be sized properly and the normal system resistance line is a reasonable distance from the stall line. The probability of stall is low. Control Engineer must have sufficient operating data to monitor operation of the fan in relation to the stall line. Proper instrumentation required monitoring fan flow, pressure and blade position.

Factor affecting the fan performance:

1) Fan vibration: The primary cause of fan vibration is fan rotor imbalance. This results from eccentricity between the center of mass and the center of rotation of the fan rotor. The level of vibration can be reduced by placing a weight on the outer diameter of the rotor opposite the mass center. Perfect balance is unattainable by practical method. Some imbalance always remains. If the fan rotor and bearing system frequency are designed to be above the fan speed, the vibration sensitivity of the fan rotor to the remaining imbalance can be reduced to acceptable levels. If imbalance of rotor increases vibration will be increased and ultimately fan cannot be run smoothly.

2) Fan **induced duct vibrations:** Fan induced duct vibrations are attributed to internal static pressure pulsations. This static pressure pulsation due to vibration of duct at inlet of the fan changes the fan inlet flow condition and fan performance.

Most occurrences of fan induced pressure pulsation can be categorized as inlet cone vortex, inlet box vortex, and rotating stall areas of flow instability.

Inlet cone vortex category of flow instability and pressure pulsation has been found to exist on large centrifugal fans controlled with radial inlet vanes. The instability occurs when inlet vane position between approximately 30 % and 70% open. Vibration level peak at 50% vane opening and reduce as the vanes are further opened or closed. This is eliminated by using radial dorsal fins at the downstream of the radial inlet vanes.

Inlet box vortex category of flow instability and pressure pulsation occurs on both inlet vane and inlet damper controlled centrifugal fans. The most common method of eliminating the problem is to install a splitter plate in the bottom of the inlet box. Fan efficiency with full open control vanes or dampers is normally improved with the installation of splitter plates and the efficiency is reduced during operation with partially open dampers.

(c) **Rotating stall category of flow instability** and pressure pulsation occurs on inlet damper controlled centrifugal fans with backward curved airfoil blades. The pulsation occurs during operation with control dampers from 0 to 30% open. Once the fan dampers exceed 30% open, pulsation returns to normal levels. The most common methods of eliminating the rotating stall problem are either to replace the inlet damper control equipment with inlet vane controls or to throttle the fan with outlet dampers instead of inlet dampers during extended operating periods with inlet damper less than 30% open.

Fan inlet duct design:

Uniform flow conditions at the fan inlet are required if the fan is to operate at design capacity. An elbow or a 90° duct turn at fan inlet prevents uniform flow and results in uneven flow distribution at the fan impeller. Due to uneven flow distribution full fan performance cannot be achieved.

4) Air **leakage through air pre-heater seals:** Air heater leakage occurs through seals on the hot and cold ends of the air heater. The majority of the leakage occurs on the cold end where corrosion due to relatively low air and gas temperature results in larger clearances between sealing surfaces. More air leakage through air pre-heater seal leads the fan to develop more flow. So, system resistance is increased due to more flow. More pressure required to overcome system resistance. So, more air leakages through air pre-heater change the FD fan performance.

Leakage through hot air ducts & cold air ducts: Air leakages through hot air duct and cold air duct have been taken into consideration for selection of FD fan sizing. More leakages affect the FD fan performance.

Excess Air: The excess airflow requirement depends on the fuel used in the boiler. If coal quality changes then excess air requirement changes i.e. total air supplied by FD fan also changes. On the other hand amount of flue gas handled by ID fan changes. So, excess air changes both fan performances.

Air ingress through the ducts: As ID fan works at lower pressure than atmospheric pressure, there is a chance of air ingress through the ducts at different areas like furnace, superheaters, economizer, air pre-heater, ESP etc. More air leakage means more amount of gas has to be handled. So, more power will be required.

Erosion of blades: Erosion of blades take place due to presence of foreign particle in the operating medium. If a fan run continuously in such medium like flue gas fan performance will fall. Centrifugal fan with

backward curved blade has low erosion potential is used as ID fan to handle the gas. The axial flow fan has a higher potential for erosion and has higher maintenance costs than an airfoil bladed centrifugal fan. That's why axial flow fan is used as FD fan, which handle fresh air.

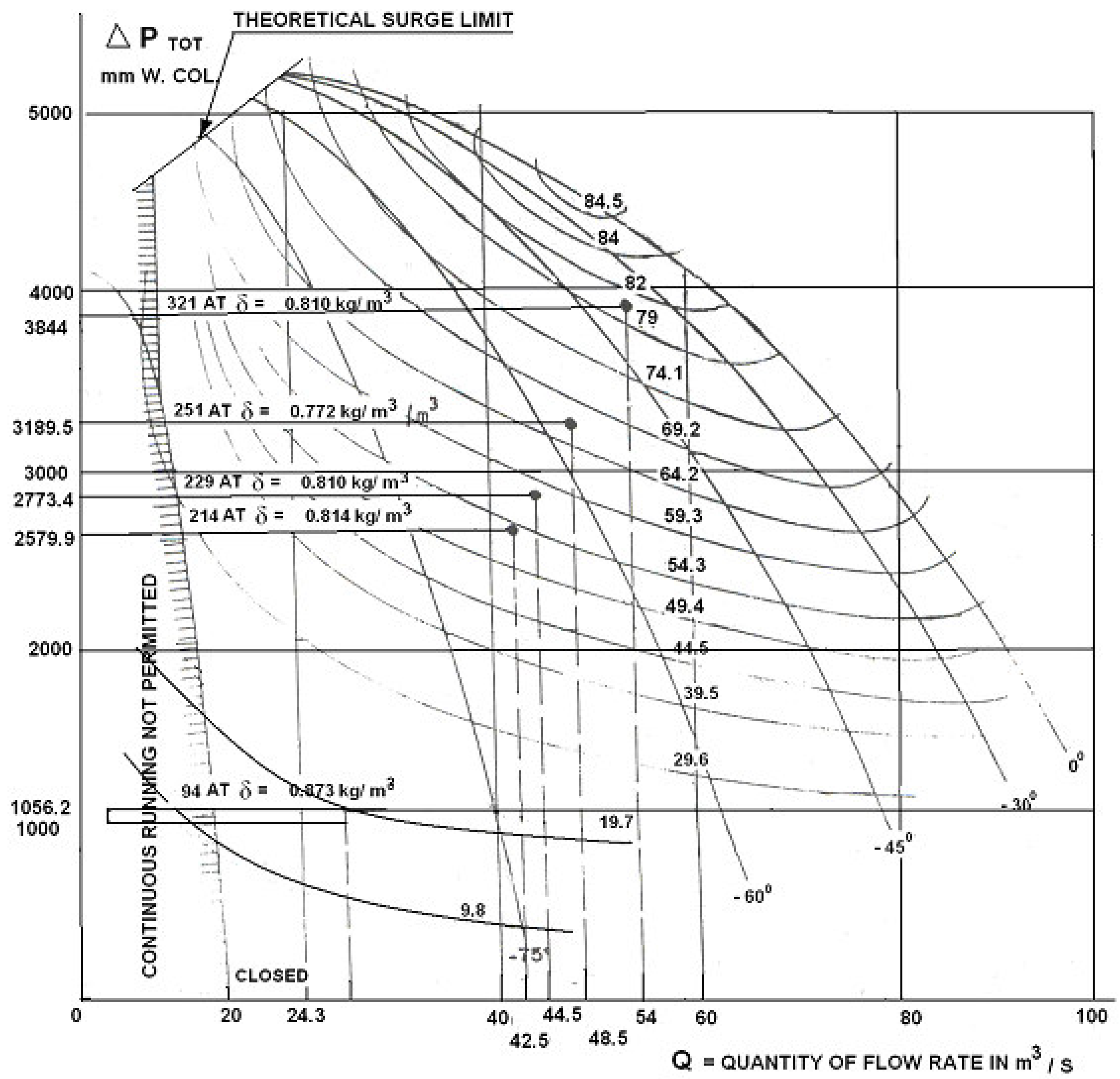
Deposits in fan blades: When a fan runs in dirty medium with high speed then some sticky particles deposit on blade. Continuous deposition in blades increases rotor imbalance, vibration also increases. So, full fan performance cannot be achieved. That is why, variable speed control centrifugal backward curved fan is used as ID fan to reduce deposition of dust on blades. The shape of backward curved blade minimizes dust build up and reduces downtime for cleaning.

Temperature of operating medium: If temperature of operating medium is varied then density of that medium charges. For a constant mass flow rate of gas volumetric flow rate changes with change in temperature. So, system resistance changes which effect on fan performance.
Fan selection criteria: Though any type of fan can be selected for a particular application, there are number of factors to be considered to get an optimum fan:
Stability in different load condition
Medium to be handled – clean or dirty.
Temperature of medium
Resistance to erosion and corrosion
Lower power input
Heat with standing capacity
Longer life of all components
Maximum efficiency
Low cost.

Technical specification of fans used in BkTPP.

FD Fan	ID Fan
Type : - AP - 1 20/12	Type - NDZV 26 BW
AP - Axial profile blade type	NDZV - Radial double suction
1 - No. of stage	26 - Tip dia in decimeter
20 - Tip dia in decimeter	WB - Broad width of impeller.
12 - Hub dia in decimeter	Medium - Flue gas
Flow - 135.4 m³/sec.	Orientation - 45° inclined suction bottom Horizontal delivery .
Head - 623 mm WC	Flow - 213.2 M³/ sec.
Temp. - 45°C	Head - 390 mm of wc
Sp. Weight - 1.0897 kg /m³	Temp. – 154°C
Speed - 1480 rpm	Sp. Weight - 0.805 kg /m³
Fan reserve :	Speed - 715 rpm.
Flow - 40.3 %	**Fan reserve**
Head - 37%	Flow - 40%
Motor rating - 1050 KW	Pressure - 44.4%
Fan weight - 14100 kg	Motor rating - 1200 KW
Orientation - Vertical suction horizontal delivery	Speed - 740 rpm
Fan regulating system- variable blade pitch angle	Fan weight - 42 tonnes
Coupling - Regiflex.	Regulating System – Inlet damper & hydraulic coupling.

PA FAN : PA fan normally handle relatively low flows and very high pressure differentials . This usually requires centrifugal fans of large dia and relatively narrow width impellers operating at high speeds. Centrifugal fans with backward curved blade is used as PA fans.



POWER CONSUMPTION ATTHE FAN SHAFT (KW) = $\frac{Q \gamma \delta}{1000 \eta}$ + BEARING LOSS

APPLICATION : INDUCED DRAFT FAN
: 740 RPM
γ - DENSITY AT DESIGN : 0.810 Kg/ m^3
δ - TEMP. AT DESIGN : 140 ^{0} C
BEARING LOSS : KW
I.D.FAN : CENTRIFUGAL

I.D.FAN PERFORMANCE CURVE

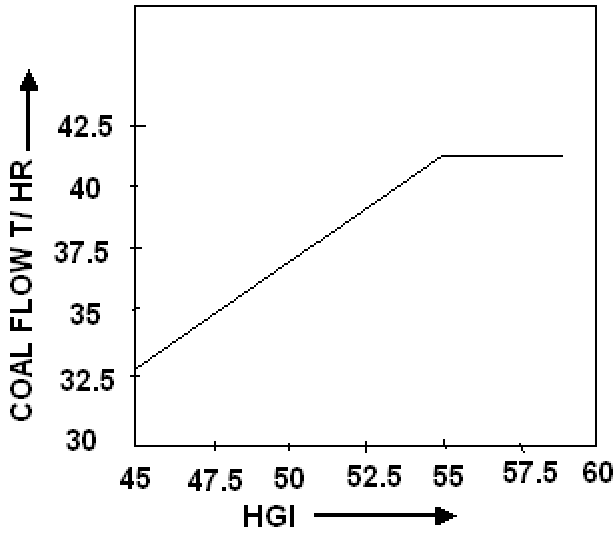


Fig.: M1

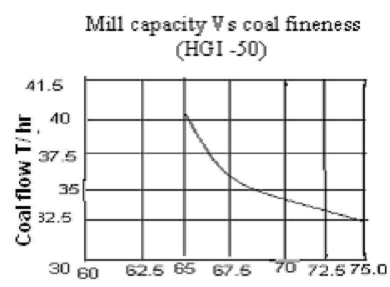


Figure - M3

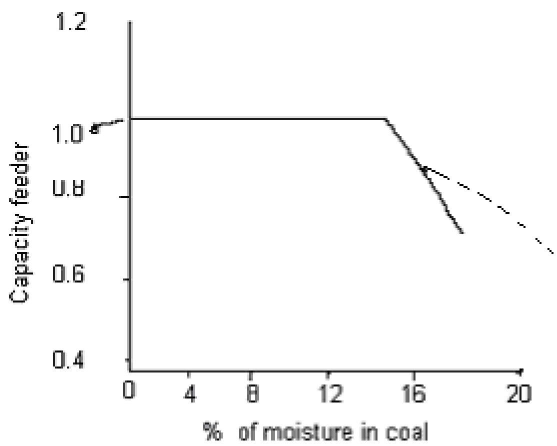


Figure - M2

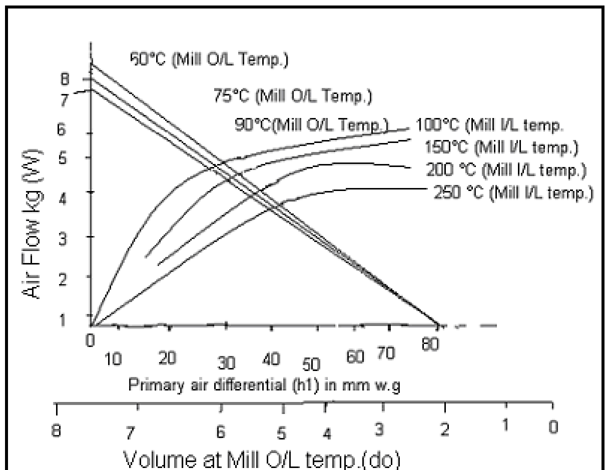


Fig.: M-4

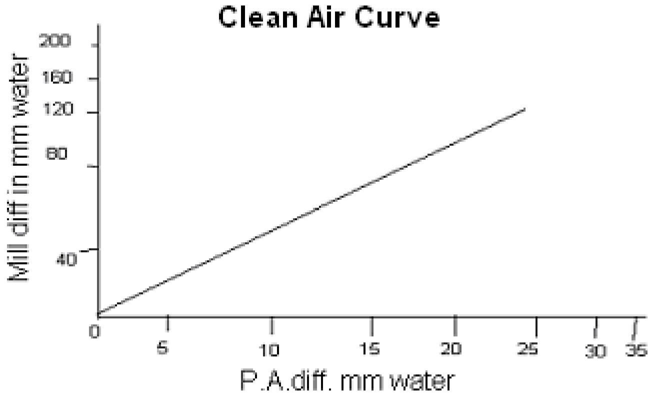


Fig.: M5

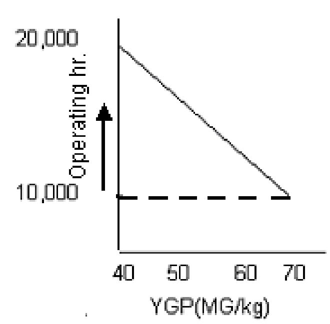


Figure - M - 8

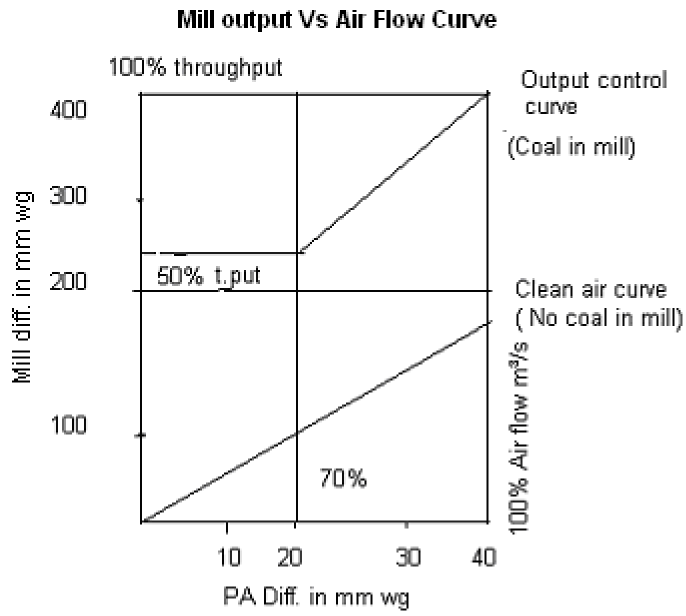


Fig.: M6

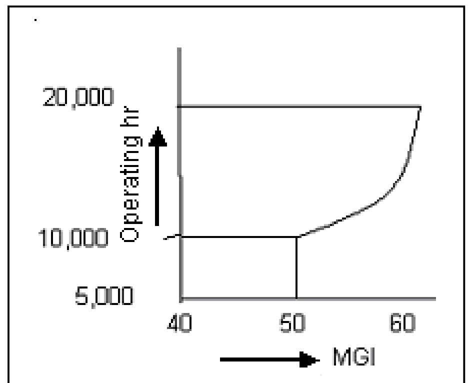


Figure - M7

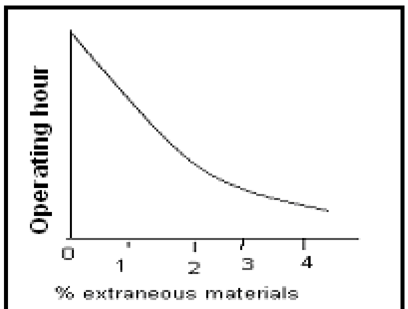


Figure M - 9

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BOILER EFFICIENCY AND ITS CALCULATION

A Boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam.

Combustion:
Combustion refers to the rapid oxidation of fuel accompanied by the production of heat, or heat & light. Complete combustion of a fuel is possible only in the presence of adequate supply of oxygen.

Oxygen (O_2) is one of the most common elements on earth making up 20.9% of air. Rapid fuel oxidation results in large amounts of heat. Solid or liquid fuels must be changed to a gas before they burn. Usually heat is required to change solid or liquid fuels into gases. Fuel gases burn in their normal state if enough air is present.

Most of 79% of air (i.e. not oxygen) is nitrogen, with traces of other elements. Nitrogen is considered to be a temperature reducing dilutant that must be present to obtain the oxygen required for combustion.

Nitrogen reduces combustion efficiency by absorbing heat from the combustion of fuels and diluting the fuel gases. This reduces the heat available for transfer through the heat exchanger surfaces. It also increases the volume of combustion by products, which then have to travel through the heat exchanger and up the stack faster to allow the introduction of additional fuel air mixture. This nitrogen also can combine with oxygen (particularly at high flame temperatures) to produce oxides of nitrogen (Nox) , which are toxic pollutants. Carbon, Hydrogen and sulphur in the fuel combine with oxygen in the air to form CO_2 , water vapour , and SO_2 releasing 8084 Kcals , 28922 Kcals and 2224 K cals of heat respectively. Under certain conditions, carbon may also combine with oxygen to form CO, which results in the release of a smaller quantity of heat 2430 Kcals / kg of carbon. Carbon burnt to CO_2 will produce more heat per kg of fuel than when CO or smoke is produced.

$C + O2 \longrightarrow CO2 + 8084$ Kcals / kg of carbon
$2C + O2 \longrightarrow 2CO + 2430$ Kcals / kg of carbon.
$2H2 + O2 \longrightarrow 2H2O + 28922$ kcals / kg of hydrogen.
$S + O2 \longrightarrow SO2 + 2234$ Kcals / kg of sulpher
Each kg of CO formed means loss of (8084 - 2430) Kcals of heat.

3 T's of combustion:

The objective of good combustion is to release all of the heat in the fuel. This is accomplished by controlling the "three Ts" of combustion, which are:

Temperature high enough to ignite and maintain ignition of fuel
Turbulence or intimate mixing of the fuel and oxygen and
Sufficient time for complete combustion.

Too much or too little fuel with the available combustion air may potentially result in unburnt fuel and carbon monoxide generation. A very specific amount of O_2 is need for perfect combustion and some additional (excess) air is required for ensuring complete combustion. However, too much excess air results in heat and efficiency losses.

STOICHIOMETRIC COMBUSTION.

The efficiency of a boiler depends on efficiency of the combustion system. The amount of air required for complete combustion of the fuel depends or the elemental constituents of fuel i.e. , Carbon , Hydrogen and sulphur etc. This amount is called stoichiometric air.

In general a certain amount of air more than that of Stoichiometric air is required for complete combustion and ensure that release of the entire heat contained in fuel oil.

FUEL ANALYSIS:

There are two methods: the ultimate analysis splits up the fuel into all its component elements, solid or gaseous, and the proximate analysis determines only the fixed carbon, volatile matter, moisture, and ash percentages. The ultimate analysis must be carried out in a properly equipped laboratory by a skilled chemist, but proximate analysis can be made with fairly simple apparatus.

PROXIMATE ANALYSIS:

Proximate analysis indicates the percentage by weight of fixed carbon, volatiles, ash and moisture content in coal. The amounts of fixed carbon and volatile combustible matter directly contribute to the heating value of coal. Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel. The ash content is important in the design of the furnace grate, combustion volume, pollution control equipment and ash handling systems of a furnace.

ULTIMATE ANALYSIS:

The ultimate analysis indicates that various elemental chemical constituents such as carbon, hydrogen, oxygen sulphur etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases. This information is required for the calculation of flame temperature and the free duct design.

CALORIFIC VALUE:

The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value (GCV) or net calorific value (NCV). The difference being the latent heat of condensation of the water vapour produced during the combustion process. GCV assumes all water vapour produced during combustion process is fully condensed. Net calorific value (NCV) assumes water leaves with the combustion products without fully being condensed.

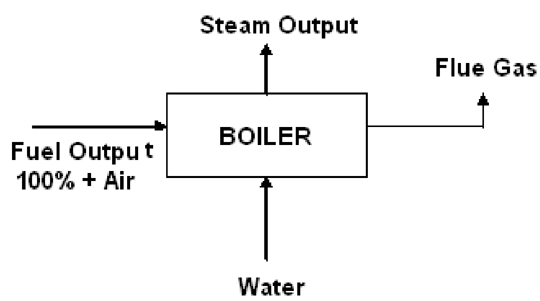
BOILER EFFICIENCY:

Thermal efficiency of boiler is defined as the percentage of heat input i.e. effectively utilized to generate steam. There are two methods of assessing boiler efficiency:

Direct Method: Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

Indirect Method: Where efficiency is the difference between the losses and energy input.

Direct Method: This is also known as "input - output method" due to the fact that it need only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency.



$$\text{Boiler efficiency} = \frac{\text{Heat output}}{\text{Heat input}}$$

Parameters to be monitored for the calculation of boiler efficiency by direct method are:

Quantity of steam generated per hour (Q) kg/hr.
Quantity of fuel used per hour (q) in kg/hr.
The working in pressure [in kg/cm²(g)] and superheat temperature (°C), if any.
the temperature of feed water (°C)
Type of fuel and gross calorific value of the fuel (GCV) in Kcal/kg of fuel

$$\text{Boiler efficiency } (\eta) = \frac{Q \text{ x } (hg-hf)}{q \text{ x } GCV} \quad \text{x} \quad 100\ \%$$

where hg - Enthalpy of saturated steam in Kcal / kg of steam
hf - Enthalpy of feed water in Kcal/kg of water.
q - quantity of fuel.

Example :

Find out the efficiency of the boiler by direct method with the data given below:

Type of boiler	:	Coal fired
Quantity of steam (dry) generated	:	8TPH
Steam pressure (gauge)/temp.	:	10 kg/cm² (g) /180°C
Quantity of coal consumed	:	1.8 TPH
Feed water temperature	:	85°C
GCV of coal	:	3200 K cal/kg

Enthalpy of steam at 10kg /cm² pr. : 665 Kcal/kg (saturated)
Enthalpy of feed water : 85 K cal/kg

So, Boiler efficiency $\eta = \frac{8x(665-85)}{1.8 \text{ x } 3200} \text{ X } 100 = 80\%$

Disadvantages of direct method

Does not give clues to the operator as why the efficiency of the system is lower.
Does not calculate various losses accountable for various efficiency levels.

Indirect method:

Indirect method is also called as heat loss method. Subtracting the heat loss fractions from 1000 can arrive at the efficiency. The standard do not include blow down loss in the efficiency determination process.
The principle losses that occur in a Boiler are:

Loss of heat due to dry flue gas.
Loss of heat due to moisture in fuel and combustion.
Air loss of heat due to combustion of hydrogen.
Loss of heat due to radiation
Loss of heat due to unburnt carbon.

In the above, loss of heat due to moisture in fuel and the loss due to combustion of hydrogen are dependent on the fuel, and cannot be controlled by design.

The data required for calculation of boiler efficiency using indirect method are:

Ultimate analysis of fuel (H_2, O_2, S, C, moisture content, ash content).
Percentage of oxygen or CO_2 in flue gas
Flue gas outlet temperature in °C (Tf)
Ambient temperature in °C (Ta) and humidity of air in kg/kg of dry air.
GCV of fuel in Kcal/kg.
Percentage combustible in ash
GCV of ash in Kcal/kg.

Solution :

Theoretical air requirement:
$=[(11.43x\ c) + \{[34.5 \text{ x } (H_2 - O_2/8)]\} + (4.23 \text{ x } S)]/100$kg/kg of fuel .

Excess air supplied (EA) = $\frac{O_2\% \text{ x } 100}{(21-O_2\%)}$

$$\text{\% of Excess Air supplied} = \left(\frac{\text{Theoretical } CO_2\%}{\text{Actual } CO_2\ \%} - 1\right) \text{X } 100$$

$$\text{Theoretical } CO_2 \text{ by volume} = \frac{\text{Moles of } CO_2}{\text{Total Moles (dry)}} \text{ x } 100\ \%$$

Total moles dry suction moles of CO_2 , moles SO_2 , moles of N_2 in flue gas .

Percentage of heat loss due to dry flue gas

$$= \frac{m \text{ x } Cp \text{ x } (Tf-Ta)}{\text{GCV of fuel}} \text{ X } 100$$

m = mass of dry flue gas in kg/kg of fuel.

Total mass of flue gas (m) = mass of actual air supplied + mass of fuel supplied

(Simpler method)
or m = (mass of dry products of combustion / kg of fuel) + mass of N_2 in fuel on 1 kg basis) + (mass of N_2 in actual mass of air we are supplying).

2. Percentage heat loss due to evaporation of water formed due to H_2 in fuel

$$= \frac{9 \text{ x } H_2 \text{ [} 584 + Cp \text{ (Tp-Ta)]}}{\text{GCV of fuel}} \quad \text{X} \quad 100$$

Where H_2 – percentage of H_2 in kg of fuel
Cp – specific heat of super heated steam (0.45 K cal / kg).
Latent heat corresponding to partial pressure of water vapour = 584 K cal / kg.

3. Percentage of heat loss due to moisture present in fuel

$$= \frac{\text{M\{ } 584+\text{CP(Tf – Ta) \}X } 100}{\text{GCV of fuel}}$$

Where , M - % of moisture in 1 kg of fuel
Cp - specific heat of super heated steam (0.45 Kcal/kg).

4. Percentage of heat loss due to moisture present in air

$$= \frac{\text{AAS x humidity factor x CP X (Tf-Ta) X } 100}{\text{GCV of fuel}}$$

Cp – specific heat of super heated steam
AAS – actual air supplied (0.45 K cals / kg)

5 . Percentage of heat loss due to un-burnt in fly ash

$$= \frac{\text{Total ash collected /kg if fuel burnt X GCV of fly ash}}{\text{GCV of fuel}} \quad \text{X} \quad 100$$

6 . Percentage of heat loss due to unburnt in bottom ash

$$= \frac{\text{Total ash collected /kg of fuel burnt X GCV of bottom ash}}{\text{GCV of fuel}} \quad \text{X} \quad 100$$

7. Percentage of heat loss due to radiation and other unaccounted loss.
For power station boiler this loss may be amount to 0.4 to 1%

Thus, Boiler efficiency (η) = 100 – (1+2+3+4+5+6+7)

Case study :
For coal fired Boiler
The following are the data collected for a boiler using coal as the fuel. Find out the boiler efficiency by indirect method.

Fuel firing rate	:	5599.17 kg/hr.
Steam generation rate	:	21937.5 kg/hr.
Steam pressure	:	43 kg /cm² (g)
Steam temperature	:	377°C
Feed water temperature	:	96 °C
% CO_2 in flue gas	:	14
Average flue gas temperature	:	190°C
Ambient temperature	:	31°C

Humidity in ambient air	:	0.0204 kg/kg of dry air
GCV of bottom ash	:	800 kcal/kg
GCV of fly ash	:	452.5 Kcal/kg
Ratio of bottom ash to fly ash	:	90.10

FUEL ANALYSIS

Ash content in fuel	:	8.63 %
Moisture in coal	:	31.6 %
Carbon content	:	41.65 %
Hydrogen content	:	2.0413 %
Nitrogen content	:	1.6 %
Oxygen content	:	14.48 %
GCV of coal	:	3501 K cal / kg

SOLUTION

Theoretical air requirement for complete combustion

$= [(11.43 \times C) + \{34.5 \times (H_2 - O_2/8)\} + (4.32 \times S)\}/100$ kg / kg of coal

$= [(11.43 \times 41.65) + \{34.5 \times (2.0413 - 14.48/8) + 4.32 \times O)] / 100$ kg / kg of coal

= 4.84 kg/kg of coal

$$\text{Theoretical } CO_2 \% = \frac{\text{Moles of C}}{\text{Moles of } N_2 + \text{Moles of C}}$$

$$\text{Moles of } N_2 = \frac{4.84 \times 77/100}{28} + \frac{1.6/100}{28}$$

$= 0.2067$

So, CO2 % = 20.67%.

Actual CO2 measure in flue gas = 14%.

$$\% \text{ of excess air supplied} = \frac{(CO2)\,\%}{(CO2)a\,\%} - 1 = \frac{20.67\%}{14\%} - 1 = 47.62\%$$

Actual mass of air supplied = [1 + EA/ 100] x Theoretical air supplied.

= 1 + 47.62] x 4.84 =7.14 kg / kg of coal.

Actual mass of dry flue gas

= Mass of CO_2 + Mass of N_2 contained in flue + mass of N_2 in combustion air supplied + mass of oxygen in combustion air.

$$= \frac{0.4165 \times 44}{12} + 0.016 + \frac{7.14 \times 77}{100} + \frac{(7.14 - 4.84)}{100} \times 23$$

= 7.569 kg /kg of coal

1. % Heat loss in dry flue gas (L1)

$$= \frac{m \times CP \times (Tf-Ta)}{\text{GCV of fuel}} \times 100$$

$$= \frac{7.569 \times 0.23 \times (190-31)}{3501} \times 100$$

= 7.9%

2. % heat loss due to formation of water from H_2 in fuel (L_2)

$$= \frac{9 \times H_2\{584 + Cp(Tf\text{-}Ta)\}}{\text{GCV of fuel}} \times 100$$

$$= 9 \times 0.02041 \times \frac{\{584 \times 0.45(190\text{-}31)\}}{3501} \times 100$$

$L_2 = 3.44\ \%$

3. % Heat loss due to moisture in fuel (L_3)

$$= \frac{M \times \{584 + Cp\ (Tf\text{-}Ta)\}}{\text{GCV of fuel}} \times 100$$

$$= \frac{0.316 \times \{584 + 0.45\ (190 - 31)\}}{3501} \times 100$$

$L_3 = 5.91\%$

4. % Heat loss due to moisture in air (L4) :

$$= \frac{\text{Actual amount of air supplied} \times \text{humidity} \times Cp\ (Tf\text{-}Ta)}{\text{GCV of fuel}} \times 100$$

$$= \frac{7.14 \times 0.0204 \times 0.45\ (190\text{-}31)}{3501} \times 100$$

= 0.30%

5. Heat loss due to radiation and convection

L5 = 0.5% (as for power station boiler it is between 0.4% to 1%)

6. % heat loss due to unburnt in fly ash

$$= \frac{\text{Total ash collected /kg of fuel burnt} \times \text{GCV of fly ash}}{\text{GCV of fuel}} \times 100$$

Ratio of bottom ash to fly ash = 90 :10

Therefore , amount of fly ash in 1Kg of coal = 0.1 X 0.0863 = 0.00863 kg

Therefore, % heat loss for fly ash (L6) = $\frac{0.00863 \times 452.5 \times 100\%}{3501}$

L6 = 0.11%

7. % Heat loss due to unburnt in bottom ash (L7)

$$\frac{\text{Total ash collected / kg of fuel burnt} \times \text{GCV of bottom ash} \times 100}{\text{GCV of fuel}}$$

Amount of bottom ash = 0.9 x 0.0863 kg = 0.077 kg

So, Heat loss in bottom ash (L7)

$$= \frac{0.077 \times 800}{3501} \times 100$$

= 1.76%

So, Boiler efficiency by indirect method

= 100 – (L1 + L2+L3+L4+L5+L6+L7)

= 100 – (7a + 3.44 + 5.91 + 0.30 + 0.50 + 0.11 + 1.76)

= 80.08%

The following are the factors influencing a boiler efficiency

Stack Temperature - The stack temperature should be low as possible. However, it should not be so low that water vapour in the exhaust condenses on the stack walls. This is important for fuels containing significant sulphur , a low temperature can lead to sulphur dew point corrosion. Stack temperature greater

than 200°C indicates potential for recovery of waste heat. It also indicate the scaling of heat transfer / recovery equipment and hence the urgency of taking on early S/D for water / flue side cleaning.

Incomplete combustion – In complete combustion can arise from a shortage of air or sulphur of fuel or poor distribution of fuel. It is usually obvious from the colour or smoke and must be corrected at the earliest.

With coal firing, unburned carbon can comprise a big loss. It occurs a gift carry over or carbon in ash and may amount to more than 2% of the heat supplied to the boiler. Non-uniform fuel size could be one of the reasons for incomplete combustion. Increase in the fines in pulverized coal also increases carbon loss as because finer coal particle may fall through grate bars or carried away with furnace draught.

3) **Excess air control:** Excess air is required in all practical cases to ensure complete combustion, to allow for the normal variations in combustion and to ensure satisfactory stack condition for some fuels. The optimum excess air level for maximum boiler efficiency occurs when the sum of the losses due to incomplete combustion and loss due to heat in flue gases is minimum. This level varies with furnace design, type of burner , fuel and process variables . It can be determined by conducting tests with different air fuel ratio.

Controlling excess air to an optimum level always results in reduction in flue gas losses; for every 1% reduction in losses 0.6% rise in efficiency.

4) **Reduction of scaling and shoot loses :**

In oil and coal fired boilers , shoot build up on tubes acts as an insulator against heat transfer. Any such deposits should be removed or regular basis. Elevated stack temperatures may indicate excessive shoot build up. Also same result will occur due to scaling on water side for not maintaining proper water Chemistry .

Higher exit gas temperatures at normal excess air indicate poor heat transfer performance. This condition can result from a gradual build up of gas side or waterside deposits. Waterside deposits require a review of water treatment procedures and tube cleaning to remove deposits. An estimated 1% loss with every 22°C increase in stack temperature stack temperature should be cheeked and recorded regularly as an indicator of shoot deposits. When flue gas temperature rises about 20°C above the temperature, it is time to remove shoot deposits.

It has been estimated that about 3mm of shoot can cause an increase in fuel consumption by 2.5% . Thus shot /slag deposition on the surface of the water wall tube, superheater, Reheater, Economiser tubes reduces the boiler efficiency considerably and increases the flue gas outlet temperature. Choking due to ash deposition on the heating element of air pre-heater also reduces the combustion air temperature and there reduces efficiency and increases flue gas temperature.

5. **Blow down control:** Boiler blow down is necessary for controlling the dissolved solids contained in the boiler water, and this is achieved by a certain amount of water is blown off and replaced by feed water. Thus maintaining optimum level of total dissolved solids (TDS) in boiler water. Uncontrolled continuous blow down is very wasteful. By monitoring boiler water conductivity and P^H blowdown can be controlled and these reducing the efficiency losses.

6. Quality of fuel: Quality of fuels influences the efficiency of Boiler to a large extent. It depends upon fixed carbon percentage, which gives a rough estimate of heating value of coal.

Volatile matter content in the coal is an index of gaseous fuels present in coal. It proportionately increases flame length, and helps in easier ignition of coal. It also influences secondary air requirement.

Ash content is coal affects the combustion efficiency and thus boiler efficiency also causes clinkering and slugging. Moisture content in fuel increases heat loss due to evaporation and superheating of vapour, helps to a limit, in binding fines, aids radiation heat transfer.

Sulphur content: Sulphur affects clinkering and slagging tendencies. Limits exit fuel gas temperature.